45TH CONGRESS, 3d Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. No. 54.

SOURCES OF MISSISSIPPI, SAINT CROIX, CHIPPEWA, AND WISCONSIN RIVERS.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING

Reports on the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers.

FEBRUARY 1, 1879.—Referred to the Committee on Commerce and ordered to be printed.

WAR DEPARTMENT,
Washington City, January 31, 1879.

The Secretary of War has the honor to transmit to the House of Representatives, in compliance with the resolution of the House dated the 21st instant, copies of reports of Capt. C. J. Allen, Corps of Engineers, on the Saint Croix River, on the Chippewa River, and on the examination of sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, with letter of the Chief of Engineers submitting the same.

G. W. McCRARY,
Secretary of War.

The SPEAKER *of the House of Representatives.*

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., January 30, 1879.

SIR: I have to acknowledge the reference to this office on the 23d instant of the resolution of the House of Representatives of the 21st—

> That the Secretary of War be, and he is hereby, requested to transmit to this House such official reports and correspondence as have been received by him subsequent to the submission of his last annual report, as relate to the improvement of the Chippewa River in Wisconsin, and the Saint Croix River in Wisconsin and Minnesota, and such as relate to the examination and survey of the headwaters of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, to determine the practicability of creating reservoirs to regulate the volume and improve the navigation of said rivers—

and to submit in compliance therewith copies of the following reports of Capt. C. J. Allen, Corps of Engineers:

1. Report of operations during the season of 1878 for improvement

of the Saint Croix River, Minnesota and Wisconsin, dated December 9, 1878.

2. Report of operations on the Chippewa River for the season of 1878, dated December 28, 1878.

3. Report of progress made in the examination of the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, to determine the practicability and cost of creating and maintaining reservoirs upon the headwaters of said rivers and their tributaries for the purpose of regulating the volume of water and improving the navigation of said rivers, &c., dated January 15, 1879.

In regard to this latter survey, Captain Allen remarks:

> In order to fully carry out the investigations ordered by Congress, at least $25,000 should be appropriated for the purpose in addition to the allotment already referred to.

The resolution of the House of Representatives is herewith respectfully returned.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

IMPROVEMENT OF CHIPPEWA RIVER, WISCONSIN.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Paul, December 28, 1878.

GENERAL: I have the honor to submit the following report of operations under my charge pertaining to the improvement of the Chippewa River, Wisconsin, for the season of 1878.

The operations were mostly confined to the improvement of the mouth of the river, and consisted in repairs upon the west jetty and extension of the east jetty for 1,700 feet, both of which works had been under construction before I assumed charge.

Work was begun early in August. The materials used were brush and stone. The stone was obtained by contract in open market, and a contract was also made for the brush, but the contractor for the latter, not furnishing it in quantity and quality to suit, the brush was cut and made up into fascines by the workmen, and the result was a better quality of material than that offered by the contractor. The brush was made into fascines, the branches left on, the fascines bound with lath-yarn. The fascines, from 24 to 28 feet in length, were then made into mats, the latter securely staked to the bottom and loaded with stone. The stone covering was 18 feet in width, excepting toward the ends of the jetties, about 1 foot in thickness near the water edge and rising towards the middle to 2 feet in thickness. The general height of the works above low-water is 2 feet.

The total quantity of material consumed in the completion of the jetties and repairs was, up to November 1—

Rock	3,514.86 cubic yards;
Brush	442.60 cords;

of which 2,734.8 cubic yards of rock and 368 cords of brush were consumed in the extension of the east jetty.

The total amount of completed work is 6,123 linear feet, viz:

East jetty	2,110 linear feet.
West jetty	4,013 linear feet.

Both jetties widen out, at their sides, to 30 feet. The east jetty overlaps that to the west by about 75 feet, a line forming their ends being parallel with the general outline of the Minnesota shore opposite.

Before the commencement of any government work on the Chippewa, the mouth of the river was incumbered by an enormous sand-bar, over which there was seldom any defined channel, and never a regular one, the depth of water at times scarcely exceeding 1 foot. The contributions of sand from the banks of the river and its tributaries found their way to the mouth, where such as was not swept away by the Mississippi spread out over a large area at the junction of the two streams. Steamers and rafts were, at times, almost entirely precluded from crossing the bar. Temporary expedients, in the shape of training-walls and dams of brush, were frequently resorted to by the raft and steamboat men in order to confine and direct the flow of water, but, being insecurely built, they were generally flanked or undermined by the current and buried up in the sand, proving, in the end, as formidable obstructions as were those they were expected to remove.

The general features of this stream are given in the report of Major Farquhar, published on page 375 *et seq.*, part 1, of the Report of the Chief of Engineers for 1875, so that it is not necessary to do more here than to refer to that report.

Upon the completion of the works, early in October, their full value was realized. Where the navigation before that time was in the highest degree precarious there is now good navigation. The depth of water between the jetties is from 3½ to 4 feet, although the direction of the channel between them is not constant. It is possible that further slight contraction of the water-way will become necessary, and, if so, it can be accomplished by projecting a series of short groins from the west jetty. Se far, however, the work has proven one of the most satisfactory of its kind.

Some additional widening of the west jetty, for about 2,000 linear feet, is advisable in order to meet the effect of overfall when the Chippewa is high and the Mississippi at a low stage.

Frequent soundings were taken, during the progress of the work, on the same line or cross-section, to note the movement of the material forming the bed, and towards the close of the work the entire area under improvement was resurveyed and the changes noted. The accompanying tracing is explanatory.

A gauge-rod was established at the mouth of the river, upon commencing work, and its readings recorded daily. Another was placed, afterwards, at Eau Claire, just above the mouth of the Eau Claire River.

Upon the completion of the principal part of the work, in October, I directed a rapid examination of the river from a point above the mouth of the Flambeau to the Mississippi in order to obtain data bearing upon the resumption of work in the spring, and, also, to ascertain more definitely the rate of erosion of the immense banks of sand known as the Yellow Banks. These banks are described in Major Farquhar's reports, and have also received description from General Warren. My assistant, who made the examination, estimates, from measurements, that the most exposed of these banks contribute, together, 1,000,000 cubic yards of sand to the river annually. He suggests that, on account of the scarcity of rock, use be made of slabs and edgings for revetting these banks. My predecessor in charge has estimated the cost of brush protection of the five high sand-banks below Eau Claire at $64,102.50, a sum that may be considerably reduced by using slabs instead of brush.

The principal natural obstructions to navigation below Eau Claire, the head of steamboat navigation, and the mouth of the river, a distance of 57 miles, consist of eight bars of sand and gravel, of various sizes and degrees of tenacity. The artificial obstructions are piers, booms, and running logs. The piers, or cribs, serve as supports to lines of booms forming pockets in which to collect the logs for scaling and distribution. The principal and the most formidable collection of piers and booms is at the entrance to Beef Slough about 20 miles above the mouth of the river. A full account of these booms is contained in the report of Mr. Charles Wanzer, accompanying.

The running of loose logs, and the practice of loggers on the tributaries of the Chippewa, and the Chippewa itself, in shutting off the supply of water, whenever they deem it necessary to do so, by means of huge dams across the streams, until enough water is collected to enable them to gather the logs above and flash them down into the reaches below, are also detrimental to the navigation below Eau Claire. The logs, flashed down thus, from reach to reach, finally enter the main stream. The dams, alternately closed and opened, very seriously affect the stages of water in the stream. The largest of these dams is at Little Falls, below the junction of the Flambeau and Chippewa. It is 625 feet long and floods an area of about three square miles. It was completed this fall.

When we consider that dams of this kind cover the Upper Chippewa and its upper and lower tributaries (it is said that there are 30 dams on the Menomonee alone), the effect of opening and closing them at random, upon the navigable portion of the river below Eau Claire, can be appreciated. And when they approach unity of action, as sometimes happens, navigation is not only seriously interfered with, but the bed of the stream is subjected to violent disturbance. The sudden "freshets" this year subjected the jetties to severe test.

The presence of a certain quantity of sand in a stream like the Chippewa is not an unmixed evil. The sand-bars, at low-water, act as dams, forming pools above them, with, generally, sufficient depth of water. Raftsmen and boatmen understand this so well that, upon entering a pool of good depth, they always look for a bar at its extremity.

Contraction of the water-way by means of jetties, training-walls, &c., so as to deepen the channels over the crests of the bars, will doubtless aid the low-water navigation, if the degree of contraction and the consequent scour be such as not to disproportion the area to the volume of discharge and thereby injure the pools above. A single jetty, or set of jetties, in a sand-carrying river, can seldom produce much useful effect, as the sand, moving from one point under the action of the concentrated water, settles, generally, at some point below, where it must be again attacked.

When we take into consideration, however, the enormous quantity of sand in motion in the Chippewa River, and discharging from it into the Mississippi, to the great detriment of the latter, it becomes evident that the protection of the Yellow Banks against erosion must accrue to the benefit of navigation upon both streams. The Loire is, probably, one of the best examples on record of a river transporting sand, and subject to sudden floods followed by long-continued periods of low-water. No measure of success, I believe, followed the attempts at improvement of the Loire until steps were taken to protect the banks of, and arrrest the discharge of sand and other material from, some of its tributaries.

No continuous survey of the Chippewa River below Chippewa Falls has been made. The stream has been examined from the falls to the mouth, and detached surveys of a number of points have been made. A thorough survey, to connect with former ones, can be made for $6,000.

The original estimate of cost of improving the river below Eau Claire was	$139, 892 50
Amount appropriated by acts of Congress approved August 14, 1876, and June 18, 1878	20, 000 00
Remaining unappropriated	119, 892 50

Mr. Charles Wanzer has been in local charge of this work, and is entitled to my thanks for the energy and zeal with which he has conducted operations. His report of operations and of his reconnaissance of the river contains so much information of interest that I herewith forward it entire.

A plotting of synchronous gauge-readings, covering a period of several weeks, of the gauges at Eau Claire and the mouth of the Chippewa, herewith, shows the oscillations at those points due almost entirely to the working of the dams. Conceding the powerful influence of such dams upon the navigation of the river, it remains to be seen, from the results of the examination now in progress as to the plausibility of reservoirs, to what extent dams and reservoirs can be utilized in improving the navigation.

Recurring to the accompanying tracing: It represents the condition of the mouth at four different periods, viz, before any work was done by the United States Government; after the west jetty was partly built; after the completion of the west and the building of 400 feet of the east jetty; and just as the main work was closing up. The soundings are reduced to mean low-water of the surveys, the fluctuations of water-surface during the periods when soundings were taken being so slight, especially during the last survey, the dams on the upper river not working, as to warrant the reductions.

Although the tracing only shows the effect to date, the work is a good example of the use of jetties in deepening the channel over a bar at the mouth of a stream when there exists a current at right angles to the axes of the jetties sufficient to sweep aside the material scoured out.

Very respectfully, your obedient servant,

CHAS. J. ALLEN,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

REPORT OF MR. CHARLES WANZER, OVERSEER.

SAINT PAUL, *December* 28, 1878.

SIR: I have the honor to submit the following report of the works constructed by me, and the examinations made during the past season on the Chippewa River.

The works constructed were situated at the mouth of the river, and consisted of the completion of the east jetty (which was commenced early in the spring under Col. F. N. Farquhar), and the necessary repairs on the west jetty, which was constructed during the year 1877.

The channel of the river, prior to any government improvement having been made, was very tortuous, and in low-water entirely unnavigable, as the mouth extended over a width of nearly three-fourths of a mile, and the volume of water was entirely inadequate to discharge the constant supply of sand which is ever pouring from this river into the Mississippi.

This was especially the case during the year 1877, until the completion of the west jetty caused a contraction in the width of the mouth and immediately produced beneficial results.

The completion of the east jetty this year has completed the design, by contracting the mouth into a space of 400 feet in width, and the result is a present 4-foot channel, as shown on the accompanying tracing.

The contracts for the work were given out early in August, to the lowest bidder, in open market, and material was first received on the work on the 14th of the same month. The stone was furnished by Messrs. Winston Bros. and Heerman, and the brush by different parties, as required, the original contract or for brush being unable to furnish the amount needed.

The rock used in construction was a lime formation, of excellent quality, such as is obtainable on the shores of Lake Pepin, and was picked up by hand and broken with sledges to the most advantageous size for handling.

Large quantities of this same material can still be obtained from that source, and from the adjoining bluffs on the Mississippi River.

The total number of linear feet of dam built during this season was 1,710, and this length makes the lower or east jetty to extend into the Mississippi River 75 feet farther than the upper. But this greater length causes no further contraction of the water of the Mississippi, as the bluffs on the shore of that river are not on an exact right angle with the jetties.

The brush used in the work was obtained from the adjoining bottom lands, and was of the best material to be found in that section, being mostly a small growth yellow birch and maple, making straight and symmetrical fascines.

These fascines were easily handled, and when laid in the work, made an almost perfect flooring of solid brush, free from interstices, even at the butts, and with the small limbs and tops remaining on, produced at the tips a perfect net-work of matted brush, and made the fascines from butts to tips not less than 24 feet in length, and of good solid brush not less than 20 feet.

The contract specifications demanded only 18 feet in length of fascines, and the difference accrued entirely to the benefit of the government and was of no extra expense to the contractors. These fascines were of an average diameter of 15 inches, and were estimated to contain 22 cubic feet of brush.

The dam built this year consumed the following amount of material, viz:

Rock	2,734.8 cubic yards.
Brush	368.0 cords.

Repairs of the west jetty consumed the following:

Rock	780 cubic yards.
Brush	62.6 cords.

Total amount for construction and repairs is—

Rock	3,514.8 cubic yards.
Brush	442.6 cords.

The brush in all cases was placed in position and staked by government labor, and there is no doubt of the fact that even the short time that has elapsed since the construction of the east jetty has proven the utility and sound judgment in having them so placed as in no instance as yet has the work constructed this year shown any of the naturally expected settlage and washing.

The jetty, as constructed, is composed entirely of brush and stone, the stone being placed on the brush so as to form a wall of 18 feet in width, 1 foot high, or deep, over the fascines at either end, and 2 feet high in the center, containing as top-load 1 cubic yard per linear foot of dam.

This width of jetty is continued until the Mississippi River is reached, where the wall is then gradually widened to an extreme width of 30 feet; the brush, in all cases, extending with their tips at least 6 feet beyond the stone.

In construction, the fascines, where the water was shallow, were laid singly and closely together, each bundle being firmly staked to the ground with stakes at least 4 inches in diameter and 5 feet in length.

Where deeper water was encountered, the fascines were made into mats of convenient size, floated into the proper position, and the corners firmly staked.

The stones necessary to sink the mat were then loaded on it, and the second tier of fascines was placed in position and sunk in the same manner, until the surface of the water was reached, then stone of the required amount was placed on the whole.

The mats in all cases were made as long as possible, generally from 14 to 20 feet, so as to avoid the danger of interstices between them. In no case did any accident happen to the work during its construction, and everything progressed rapidly to a satisfactory completion.

The weather was propitious for the contractors to procure stone from Lake Pepin, only 3 days being lost during the season on account of winds, while early in the spring, during the space of 32 days, only 12 were found practicable for working, the high winds driving the steamboats and barges out of the lake during the balance of the time.

The contract-price paid for stone for this work would appear on first sight to have been extravagant, but when it is considered that every load of rock had to be windlassed from the mouth to the place of unloading, and that on the most successful days, with two steamboats and full crews, only five loads could be delivered, the price paid per yard would not appear in disproportion to the amount of work required to deliver the stone, and I am satisfied that the interests of the work were served by giving the contract to the beforementioned firm.

The repairs to the completed west jetty were necessary on account of its settling in places, which settlage I believe to be almost entirely due to the fact that the fascines were laid on bars largely composed of sawdust from the mills on the upper river. These bars are very easily washed when once any seepage or percolation has taken place. The work of repairs consisted of raising the sunken places by means of rock and brush, and of widening the dam where the most likelihood of a break appeared.

The west jetty, from the island to the mainland (with the exception of that repaired this year), should be widened and strengthened at the earliest opportunity. It is now so narrow (in some places only 8 feet wide), that any great amount of water running over it in the spring floods of the Chippewa, with a possible low stage in the Mississippi River, would endanger one of the most important portions of the work.

The benefit to the river, caused by these improvements, can hardly be estimated. Lumbermen and steamboatmen all cheerfully bear witness to the advantage therefrom, and all are anxious that the works should be so strengthened as to insure their stability.

On October 2, 1878, I left Saint Paul, under your instructions, and proceeded to gauge the tributaries and main Chippewa, from the mouth of Yellow River to the Mississippi, and to make an examination of the "Yellow Banks," said to be situated between Chippewa Falls and the mouth of the stream.

The first bank encountered is situated at Chippewa Falls dam, has a total length of 2,700 feet and an average height of 85 feet, but, being located above the dam in quiet water, no sand of any amount is washing from it.

The river from Eagle Rapids to this place is free of sand, and has a hard gravel bottom and a 5-foot channel. Before the various dams were built on this portion of the river there were many rapids, which are now entirely flooded out.

The second "yellow bank" is located at Eau Claire, also immediately above the dam, and therefore in quiet water, and doing no damage.

There is a small "bank" located about 1 mile below the mouth of the Eau Claire River, nearly three-eighths of a mile in length and 20 feet high, estimated to have thrown into the river about 14,500 cubic yards of sand within the last 15 years.

The first large "yellow bank" in descending the river is known as the "Twelve-mile Bank," and is situated in section 31, township 27 north, range 10, and is 6,300 feet long. The up-stream 3,100 feet of the above length is covered at the upper part of the slope with vegetation and soil, but the bottom of the bank has commenced sliding out.

The balance of this "bank" (3,200 feet) is free from trees, and is one continuous range of sand 175 feet high, and constantly washing into the river.

The amount estimated to have washed from this bank within the last 15 years is 2,077,777 cubic yards. Below this place appears the first sand-bar of any account, the river bottom to this point being coarse gravel and the channel generally good.

The Mary Dean "Banks" are next in order in descending the river, and are located in township 26, range 11, sections 5 and 6, and in sections 31 and 32, township 27, range 11.

I here obtained what I deem authentic information in regard to the wash of these banks from Mr. Garland, one of the owners of the mills at this place, and a 20 years' resident.

These "banks" are 6,900 feet long, with an average height of 145 feet, and the slope runs directly into the river. They are composed entirely of fine sand, and from information gained it is estimated that during the last 15 years at least 4,632,000 cubic yards of this material have washed into the stream.

Ramsey's Landing "Yellow Banks" are the third (after leaving Eau Claire) of any size. They are located in sections 1 and 2, township 26, range 12, are of same material as last "bank" mentioned, and are estimated to have thrown 4,264,813 cubic yards of sand into the river during the last 15 years. These "banks" are 4,700 feet long, with an average height of 140 feet above the river. From a 22 years' resident at this place I obtained data upon which to base my calculations, he having on his first arrival at the locality built a certain fence of a given length, from a known point, to the then edge of the river bank. The portion of the fence not washed away is still standing, and the old channel marks corroborate the calculations made from this source of information.

"Waubeek Yellow Banks" are situated at the mouth of the Waubeek Slough, in section 4, township 25, range 13, and are 3,800 feet long, with an average height of 135 feet. The central portion of this bank is as yet throwing no sand into the river, but the upper 2,000 feet and the lower 700 feet are in present need of improvement, and are estimated to have discharged during 15 years the sum of 871,760 cubic yards of sand.

The above include all the "banks" of any size which now contribute to the sand in the Chippewa River, and the aggregate discharge, as per above estimates, reaches the sum of 11,846,352 cubic yards for a space of 15 years. This estimate I know to be a low one, and I have no doubt that a more careful examination would establish the fact that 1,000,000 cubic yards of sand are annually moving from these banks into the river, causing shifting bars and tortuous channels in the Chippewa, and eventually reaching the Mississippi River, there to cause obstructions to navigation and a never-ceasing expense to the national government. There is no doubt but that one of the ultimately best improvements that could be made for the Chippewa River would be the stoppage of the running sands in these banks. The damage caused by this discharge of sand into the Mississippi is apparent anywhere below the junction of the two rivers. It being impossible for any quantity of sand to come through Lake Pepin, the bars below the lake must be attributed almost solely to the discharge from the Chippewa.

In my examinations I also noted the sand bars which were causing the most trouble in navigating the river, and would note as follows, viz:

Sebastopol Bar, located below Twelve-Mile Yellow Bank.
Hoghole Bar, located below Ramsey Landing Yellow Bank.
Hawkin's Bend, located 1½ miles below Ramsey Landing Yellow Bank.
Bear Creek Bar, located short distance above Durand.
Plum Island Bar, located at head of Plum Island.
Ed. Ray Bar, located 6 miles above mouth of river.
Fred. Young Bar, located 4 miles above mouth of river.
Flower-Pot Bar, located 2½ miles above mouth of river.

The above are in order named as you are coming down the river, and are designated as known to river men.

The first three are gravel bars; the balance are composed almost entirely of sand. But I found no bars below Eau Claire on which the gravel exceeded 1 foot in depth, and once this crust is removed, the action of the water would, without difficulty, wash them away. For the removal of the sand bars a contraction of the river is needed, either by means of wing-dams or jetties. The Flower-Pot Bar will require a dam across the entrance into the Little Missouri, and a training dam of 1,400 feet in length from the shore above to the upper end of Flower-Pot Island.

If practicable, there is no doubt but that the simplest and most effectual method of improving the river below the head of "Big Beef Slough" would be to either dam the head of that slough entirely, or at least construct a dam which at low water would retain its present discharge in the main river, allowing only the surplus in high stages to find an outlet through the slough. (See gauging of Beef Slough.)

The artificial obstructions in the river below Eau Claire consist of sheer-booms and piers.

The first sheer-boom is located 1 mile below Eau Claire, is a swing, and when in position completely closes the channel. The piers at or near the same location are built of timbers and loaded with stone, and being near the middle of the river, are of course a detriment to navigation.

The second large boom is 2 miles above the Mary Dean Mills, and is also a swing. There is also a range of boom piers from this locality, extending to the mills, having the same objections as the first piers mentioned, only they are more detrimental.

Round Hill boom, 1½ miles above the head of Beef Slough, is the largest on the river, stretching as it does from Round Hill to the head of the old channel leading into the slough, a distance of 3,000 feet.

Complaints are made against the location of this boom and the neglect of opening it when passing boats require it. The swing or open end of the boom is directly under a high perpendicular rock, known as "Seeping Rock," and during the nights it is very difficult for boats to find the opening at the end of the boom, on account of the dark shadow from the rocks overhead. The object of this boom is to turn loose logs into the head of Beef Slough, and also to divert as much of the Chippewa River as possible into the same channel. No protection is afforded against the logs jamming the boats against the rocks when the boom is suddenly opened. The above constitute the principal artificial obstructions to navigation in the river, but the fact of loose logs being allowed to be run below Eau Claire is, in reality, the most serious danger to boats and rafts, and it would seem absurd to an observer for the people of the Chippewa Valley to ask the government for appropriations to improve navigation while they themselves are every year allowed to fill the river with the most dangerous of obstructions; and this leads me to speak of the status of affairs between the different lumbering interests of this river. One interest, logs, on the Upper Chippewa and Flambeau Rivers, run their logs to Eau Claire, and there manufacture them into lumber, then raft and run the lumber to the Lower Mississippi markets. Another interest runs their loose logs the whole length of the Chippewa to the head of Beef Slough, and down the slough to the Mississippi River, where they are rafted for down-river mills.

This running of loose logs and diversion of the waters of the river to Beef Slough has given rise to a series of suits, the culmination of which is expected to take place this winter in a United States court, and the legality of loose-log navigation will probably be definitely settled. The loose logs calculated to be run by this interest amount annually to 200,000,000 feet, and one can readily imagine the danger in running steam craft through their high-water "drives."

All interests are united in desiring improvement to the river below the head of Beef Slough, and above where there will be no danger of Beef Slough operations causing them to conflict with government authority.

The lumber interests of the Chippewa River are very extensive. In good seasons about 2,000,000 feet of sawed lumber per day are manufactured and shipped, besides the 200,000,000 feet per year of loose logs. The question of the sawdust from such an amount of lumber being allowed to run into the river is one that should receive the notice of those in authority.

The Beef Slough Company, which are the parties running loose logs on the river, is a wealthy corporation, having 20 saw-mills on the Mississippi River, located at Winona, Lyons, McGregor, Dubuque, Clinton, Moline, Rock Island, Davenport, Muscatine, and Saint Louis.

The corporation is composed of the following companies: The Beef Slough Boom Company operate in the slough, store the logs, and turn them into pockets for the different owners; the Mississippi Logging Company cut and haul the logs into the Chippewa, and do the rafting at the Slough; the Chippewa Improvement Company do the "driving," and have built all the dams on the river and tributaries, which are controlled by the Beef Slough Company.

The following is information obtained in reference to location and size of dams on the Chippewa and Eau Claire Rivers, for which I am under obligations to Mr. B. P. Swift, of the Beef Slough Company, and Mr. W. A. Rust, of the Eau Claire Lumber Company:

1st. Lower Elk River Dam, located in northwest of southeast quarter of section 11, township 37, range 2 west.

Height of gates above foundation	10 feet.
Width of gateways	28 feet.
Length of dam	200 feet.
Area of flowage	1 square mile.

2d. Upper Elk River Dam, located in southeast of southeast quarter, section 14, township 37, range 1 west.

3d. South Fork Flambeau Dam, located southwest of southwest quarter, section 23, township 40, range 3 east.

Height of gateways above foundation	10 feet.
Width of gateways	32 feet.
Length of dam	140 feet.
Area of flowage	over 4 square miles.

4th. East Fork of Chippewa, located in southeast of southeast quarter, section 26, township 41, range 24 west.

Height of gateways above foundation	9 feet.
Width of gateways	40 feet.
Length of dam	450 feet.
Area of flowage	2 square miles.

5th. West Fork Chippewa, located in southwest of southwest quarter, section 14, township 41, range 6 west.

6th. Rice Creek Dam, situated in southeast of southwest quarter, section 21, township 33, range 8 west.

Height of gateways above foundation	9 feet.
Width of gateways	22 feet.
Length of dam	130 feet.
Area of flowage	¾ square mile.

7th. Paine Creek Dam, located 6 miles above Chippewa Falls.

8th. Chippewa Falls Dam, constructed in 1877 and 1878, consists of dam and lock.

9th. North Fork of Eau Claire Dam, situated in township 29, range 4 west.

Height of piers	10 feet.
Area of flowage	320 acres

10th. North Fork Dam No. 2, located in township 27, range 4 west.

Height of piers .... 22 feet.
Area of flowage .... 1,000 acres.

11th. South Fork Dam, located in township 27, range 3 west.

Height of piers .... 20 feet.
Area of flowage .... 800 acres.

12th. Little Falls Dam, located in southeast of northwest quarter of section 28, township 32, range 6 west.

Height of gateway above foundation .... 16 feet.
Length of dam .... 625 feet.
Breadth of ordinary water-way .... 147 feet.
Total breadth of gateways .... 228 feet.
Area of flowage .... 3 square miles.
Amount of water for flowing purposes .... 1, 000, 000, 000 cubic gallons.

This dam was completed this fall, and it is calculated by the projectors of the work that by the use of it for flooding purposes they can raise the water at the head of Beef Slough at least 3 feet.

On one trial made this fall, the following results were obtained:

Gates were shut down November 8, at 9 a. m., causing the river to fall at Eau Claire on the 10th one foot.

Twenty gates were opened on November 13, with a 15 feet and 10 inches head of water, and were allowed to run for twenty-four hours.

Water below dam raisese .... 6 feet.
Water at Eau Claire raises .... 4. 6 feet.
Water at Durand raises .... 3. 1 feet.

It is to be regretted that more information could not have been obtained in reference to this flooding, but with the exception of the above such as I have conflicts to such a degree as to make it unreliable. But certain it is that by shutting down this dam in low-water the Lower Chippewa is rendered unnavigable. The constant floodings to which this river is subjected during the year is one cause of the difficulties experienced in crossing sand bars.

Even in the low-water season, but with the dams all opened, to insure a steady stage, the river will soon wear for itself a navigable channel, only to be entirely destroyed by the first flood which causes the flattening out of the adjacent bars.

In conclusion, it only remains to report what seems to be the most urgently required improvements for the river, which are—

First. The widening of the west jetty at the mouth for a distance of 2,000 feet, and for this I would suggest a widening of 8 feet as sufficient to insure the safety of the work, which widening could be accomplished for the sum of $3,000.

Second. The improvement of the Flower Pot Bar.

Third. The improvement of the Hog Hole Bar.

Fourth. The improvement of the Hawkins Bend Bar.

These are regarded the most important by all interested in the improvement of the river.

The stoppage of the running sand of the Yellow Banks is a matter that should be considered in connection not only with the Chippewa, but also the Mississippi River.

From inquiries, I believe that the revetting of these banks can be done with the refuse lumber from the mills above. Stone for the work would be very expensive, as there appears to be none convenient to the river.

These slab and lumber retaining walls are in common use at and around Eau Claire, and, after being constructed for twenty years, are apparently as serviceable as when first built.

Respectfully submitted.

CHARLES WANZER,
Overseer.

Maj. CHARLES J. ALLEN,
Corps of Engineers, U. S. A.

IMPROVEMENT OF SAINT CROIX RIVER, MINNESOTA AND WISCONSIN.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Paul, December 9, 1878.

GENERAL: I have the honor to report the following operations during the season of 1878, for the improvement of the Saint Croix River, Minnesota and Wisconsin, under the appropriation of $10,000, made by act of Congress approved June 18, 1878.

I made a personal examination of this stream early in August, from Stillwater, at the head of the lake, to the Dalles, a distance of about 30 miles. The stage of water in the river was unusually low, and the opportunity favorable, therefore, for observing the configuration of the channel and the obstructions in it.

The obstructions are, as stated in the report of my predecessor, Major Farquhar (page 372 *et seq.*, Report of the Chief of Engineers for 1875), of two kinds, natural and artificial. To the first class belong snags, stumps, and bowlders; to the second, cribs, piles, and booms. Many of the cribs have been abandoned for years and left in the channel, becoming obstructions to navigation. It was evident that the first need of navigation was the removal of the obstructions above the booming grounds. Under authority from the Chief of Engineers, the necessary flat-boats, tackle, and tools were purchased, the work to be done by hired labor. The immediate supervision of the working parties was intrusted to Capt. O. F. Knapp, whose long acquaintance with the stream and its navigation gave promise of intelligent adaptation of the means to the ends. He commenced work about the middle of August, moving down stream from Taylor's Falls, and has successfully prosecuted it to date, having removed, to December 1, all the principal obstructions to navigation to a point about 3 miles below Osceola, besides protecting 800 feet of bank by means of brush and stone revetment. The work is still in progress, although the boats have been laid up for the winter.

The boom grounds above referred to extend up stream from Stillwater for about 8 miles. The booms cover the entire portion of this reach, excepting that occasionally a small and insufficient passage is opened for steamers. Steamers are sometimes entirely excluded, especially during the months of June and July, when the logs run in great numbers. These logs are received into the pockets formed by the lines of cribs, piles, and booms, where they are "sealed" and thence distributed. The time seems to be approaching when it will be necessary to define the limits of the booms in the interest of navigation. I cannot do better, in this connection, than to quote from the report of Major Farquhar, page 374, Report of Chief of Engineers for 1875, where he says:

> As in other reports on rivers, where lumbering is the predominant interest, I respectfully suggest that if the United States is to improve this river by removing natural obstructions, some provision must be made to prevent the placing of artificial ones.

The examination of this river in 1874, upon which the report of that year was based, was necessarily incomplete, owing to lack of funds. In order to meet questions which have arisen, and others which are likely to arise, a complete low-water survey is desirable, especially of the extensive area known as Page's Slough, where the logging interests propose the excavation of a narrow artificial channel as an offset to the navigation interests for excluding them from the main river. This project does not meet with favor among the owners of steamboats.

The distance from the Dalles, the head of navigation, to the Mississippi, is 55 miles, to survey which distance thoroughly would cost $5,000.

The original estimate for the improvement of this stream was $21,758. From the experience of the past season, I shall place the cost at $35,000; leaving, after deducting the amount appropriated by the last Congress, $25,000 as the amount necessary to complete the improvement.

Very respectfully, your obedient servant,

CHAS. J. ALLEN,
Captain of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A.

PRELIMINARY REPORT UPON EXAMINATION OF THE SOURCES OF THE MISSISSIPPI, SAINT CROIX, CHIPPEWA, AND WISCONSIN RIVERS, TO DETERMINE THE PRACTICABILITY AND COST OF CREATING AND MAINTAINING RESERVOIRS UPON THE HEADWATERS OF SAID RIVERS WITH A VIEW TO IMPROVING NAVIGATION OF SAME.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Paul, January 15, 1879.

GENERAL: I have the honor to submit the following progress report of the examination of the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, ordered by act of Congress approved June 18, 1878. The reading of the act being as follows:

The examination of the sources of the Mississippi River, and of the Saint Croix River in Wisconsin and Minnesota, and of the Chippewa and Wisconsin Rivers in the State of Wisconsin, to determine the practicability and cost of creating and maintaining reservoirs upon the headwaters of said rivers and their tributaries, for the purpose of regulating the volume of water and improving the navigation of said rivers and that of the Mississippi River, and an estimate of the damage to result therefrom to property of any kind.

Preceding this was a resolution of Congress approved December 15, 1877, as follows:

Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of War be, and he is hereby, requested to make such preliminary examination of the headwaters of the Saint Croix, Chippewa, and Wisconsin Rivers, in the States of Minnesota and Wisconsin, as is consistent with his service to determine the extent and practicability of reservoirs upon the same, and report to this Congress the result of such examination together with a compilation of all information and reports in his office bearing upon the subject of reservoirs, by February 15th proximo, or as early thereafter as practicable, and that he also report the estimated amount and character of the lands which would be submerged by such reservoirs.

From inspection of the above, it appears that the points to be particularly determined are:

1. The practicability of establishing reservoirs.
2. Cost of creating and maintaining them.
3. The amount of damage to property therefrom.
4. The extent to which the impounded water can be applied to the improvement of the navigation of each stream and ultimately to that of the main Mississippi.

The sum of $20,000 was allotted for the examinations.

The area of country under consideration is immense, covering a large portion of Minnesota and Wisconsin, requiring actual examination of not less than 25,000 square miles, and involving consideration of the entire watershed tributary to the Mississippi River, at least as far down as the mouth of the Wisconsin.

The greater part of the regions to be examined is difficult of access, sparsely settled, and little known, excepting to lumbermen who have had almost exclusive control of the smaller streams, especially so in Wisconsin.

The reservoir project has attracted attention for a number of years past, having had its advocates and opponents, the advocacy or opposition based, frequently, upon misconceptions as to the character of the country and the streams, and, as frequently, from conflict of interests.

The general interest in the subject has called forth several able though preliminary reports, the principal among them being: Report by Maj. G. K. Warren, Bvt. Maj. Gen., U. S. A., April 30, 1870, contained in Annual Report Chief of Engineers, 1870; report by Maj. D. C. Houston, Bvt. Col., U. S. A., January 21, 1878; report by Major and Brevet Lieutenant-Colonel Farquhar, February 4, 1875, contained in Annual Report

Chief of Engineers, 1875; and subsequent reports by the same officer January 23, 1878.

The report of February 4, 1875, upon the sources of the Mississippi, and the report of February 8, same year, by the same officer, forming part of the general report upon transportation routes to the seaboard, contain so full description of the natural features of the country and river from the sources of the Mississippi to the Falls of Saint Anthony, that it is unnecessary to undertake further description of this part of the country under examination.

The examination of 1870 was called for partly from the necessity of restraining or controlling for a time the flow of water at the Falls of Saint Anthony, to facilitate the work undertaken by the citizens for the preservation of their water-power. The preservation of the falls, however, passing into the hands of the United States engineers, definite plans were carried out, and the question of restraining the floods remained in abeyance until 1874, when the examination of the sources of the Mississippi was ordered, mainly in the interest of navigation.

The survey of 1874 was as complete as the means at disposal would admit of, and, generally, so thorough that the examinations made under my direction this past year, added to the former, enable me to report the survey of this part of the region under consideration as practically completed, the few exceptions to which to be noted further on.

The reports previously made upon the sources of the Saint Croix, Chippewa, and Wisconsin Rivers were based upon information collected at short notice, and from the land maps, the latter being inaccurate in many instances, especially in regard to the meanderings of streams, connections of systems of small lakes, &c., and affording no information as to slopes excepting that to be inferred from the general courses of the streams. These maps, however, have served the purposes for which they were originally designed, and have been of great use to our parties as guide-maps. The question as to the feasibility of reservoirs having been fairly entered upon, should be exhausted, in order that the matter may be disposed of.

The question of damage to property, if taken in its broadest sense, calls for as much research as for any other involved. Not to speak of overflowed land, though much that would be overflowed is, at present, of little value, the ultimate effect upon the running of logs has to be considered, as well as that upon the operation of mills, &c. The lumbermen (loggers, properly speaking) have been in the habit, for years, of building dams at will upon the tributaries and the main streams as well, many of the dams of a permanent character and erected at great cost, while others are temporary structures or "cut-away" dams. These dams pond up the water until a sufficient quantity is collected so that the logs may be floated down to the dam, when they are driven or flashed through, or over, according to the construction of the dam, depending upon the head of water into the reach below, the process to be repeated at the next lower dam. The term "cut-away" is applied to a cheap, temporary dam without gates or sluices, erected to collect the water above it; sufficient water being collected, an opening is made in the dam, the logs run through, and the dam abandoned. This irregular, unsystematic interference with the flow of water, while subserving the interests of the loggers, is very injurious to the low-water navigation for steamers and rafts, in the navigable reaches of the Saint Croix and Chippewa Rivers, especially. The detriment to navigation on the Chippewa River during the low-water season of 1878 is fully set forth in my report, and the appendices thereto, of December 28, 1878. The loose logs floated down in this way are "boomed" at points below, made up into rafts, and floated to their markets. As a general rule, the raft and steamboat interests conflict with logging interests. I may remark here, that the word navigation, when used by the loggers, refers to the running of loose logs.

The opening and closing of the dams doubtless affects more or less the operations of mills run by water-power, though to what extent, and whether the control of the flow by means of reservoirs managed in the interests of steamboat and raft navigation would be acceptable to all the mill proprietors, can only be ascertained after more thorough research. The probability is that the creation of reservoirs will prove of benefit, generally, to the logging interests.

The physical data required, in order to a full discussion of the subject, are:

Available supply from rainfall and areas of watersheds.

Discharges of the streams to serve as checks upon calculations from the above.

Capacities of reservoirs.

Capacities of channels to carry off the impounded water in sufficient quantity.

Nature of the streams to be improved, to be ascertained by examination and survey.

The most difficult factor to determine is the available amount of rainfall, that is, the amount that actually finds its way into the streams, to multiply into the area of watershed. The determination of the quantity of rain and melted snow for a period of years at, or in the vicinity of, each reservoir, would be a desirable precedent to any sort of conclusion in the case. The available supply from rainfall is affected by various items of loss; as infiltration, absorption by vegetation, and evaporation; the latter varying as the area of surface exposed, and, further, affected by temperature, wind, &c.

ORGANIZATION.

The amount of money available only allowed of placing three regular parties in the field; one to complete, as far as possible, the examination at the sources of the Mississippi; another, to examine the sources of the Saint Croix; and a third, charged with the examination of a part of the sources of the Chippewa and the Wisconsin Rivers. Two flying parties were afterwards added: one to gauge the discharge of the Saint Croix River from the Namakagon to Taylor's Falls; and another to gauge the Chippewa at points below the junction of that stream and the Flambeau, and to connect, by transit and level, the system of lakes at the sources of the Flambeau with a point on the Wisconsin Central Railroad, thereby bringing the larger part of the areas under examination in Minnesota and Wisconsin into close connection, the levels all to be ultimately referred to mean sea level.

The partie did not take the field until about the 22d of August, so that not more than two and a half months' actual field work was accomplished, yet within this short period a large amount of valuable information was acquired, although, from the necessity of supplementing much of it by further examination, only a portion of that gained is in shape to be presented.

In addition to the field work, circular letters were addressed to prominent lumber firms and others connected with the working of dams, raft and steamboat interests, &c., asking for specific information. In this way many valuable facts were acquired.

Gauge-rods were established at important points and read daily; and, in addition, observations for rainfall were insured at the Leech Lake, Red Lake, and White Earth Agencies, for the sources of the Mississippi, in addition to which observations for evaporation were provided for at Red Lake and White Earth.

In the division of labor of the office, Mr. J. D. Skinner, assistant engineer, who made the surveys at the sources of the Mississippi, in 1874, under direction of Colonel Farquhar, was placed in general supervision of the field parties, and his activity and zeal, joined to a full appreciation of the subject in hand, contributed largely to the successful work of the season.

The work in Wisconsin was especially difficult and tedious. The whole of the watershed under examination is a mass of lakes and streams, with few marked features to attract the eye of the engineer as key-points, and frequently no indication of the existence of lakes and marshes until they are actually encountered.

The mode of procedure in the examination of sites for reservoirs was, to ascertain in advance, from the most trustworthy sources, generally from lumbermen or explorers, the most eligible sites; then to reconnoiter the position, and, after assuming a height for the dam, to ascertain, by level and transit, the capacity of the reservoir and the plane of flowage, understanding by the latter the line in which a plane of true level passed through the crest of the dam would intersect the surface of the country above the dam and adjoining. The swell or amplitude was not taken into consideration.

Each party was provided with apparatus for measuring rainfall and evaporation. The results from these observations are, of course, meager, yet it was thought that such data would be so much gained, the absence of which might in future be regretted.

Each party was also instructed to gauge the discharge of streams, to note the location and dimensions of all existing dams in the country passed over, to collect information as to building materials, and, in fine, to neglect no item of information pertinent to the subject.

The report of Assistant Skinner, hereto appended, gives the details of operations and also describes the natural features of the different basins, so that it is only necessary to refer to it for those items.

The methods of computation and the means of arriving at results have been discussed almost daily by myself and assistants.

A report by Mr. J. P. Frizell, assistant engineer, giving the results of his researches upon rainfall, evaporation, &c., is also appended. This paper is of value, Mr. Frizell having had several years' experience in planning and constructing supply reservoirs in the Eastern States.

THE SOURCES OF THE MISSISSIPPI.

The examinations of 1874 resulted in the recommendation of several dams for reservoir purposes at Leech Lake, Mud Lake, Lake Winnebigoshish, below the mouth of Vermillion River, at Pokegama Falls, on Pine River, and at Gull Lake. The sites at Gull Lake and on Pine River were not re-examined this year. Our examinations at the sites of the others proved the correctness of judgment in the selection of those points and in the heights of dams proposed. Our more extended investigations resulted in slight changes as to location, and caused also slight changes in dimensions of the dams. Borings were made at the proposed sites for the dams at Leech, Mud, and Winnebigoshish Lakes, and also for the Vermillion River dam. These borings showed the existence of a stiff blue clay underlying the sand and other alluvion. The depths are shown on the accompanying tracings. No borings were made at any other points. The Pokegama Falls dam can be constructed upon solid rock.

The dams found practicable are—

1. *At the efflux from Lake Winnebigoshish.*—A dam to be 14 feet high and 1,114 feet in length, the estimated cost of which is $59,969.80. This dam will pond the water up into Cass Lake through the Mississippi River, affording a reservoir capacity of 45,754,204,380 cubic feet, the area of reservoir surface being 4,312,701,360 square feet, and the area of the basin from which it draws its supply 527,459,328,800 square feet.

2. *Leech Lake.*—A dam at its efflux in Leech Lake River, 4 feet high and 3,300 feet long, affording reservoir capacity of 22,567.564,800 cubic feet; the surface area of reservoir being 6,091,430,400 square feet, and the area of supply basin 27,906,278,400 square feet. To cost $55,000.

3. *Mud Lake dam.*—On Leech Lake River, just below the wild rice fields known as Mud Lake. The dam to be 6 feet high and 1,000 feet long, causing a reservoir capacity of 2,885,414,400 cubic feet; the area of reservoir being 480,902,400 square feet, and the area of basin from which it draws its supply of rainfall 4,460,544,000 square feet. To cost $31,737.20. This dam will pond up the water to the foot of the Leech Lake dam.

4. *Dam on the Mississippi River below the mouth of Vermillion River.*—To be 10 feet high and 2,300 feet long. Capacity of reservoir, 5,770,828,800 cubic feet. Area of reservoir, 961,804,800 square feet, and area of supply basin 12,071,346,800 square feet. To cost $56,245.20. This dam will pond the water up into Leech Lake River, Ball Club, and Stephen's Lakes.

5. *Dam at Pokegama Falls.*—To be 7 feet high and 400 feet long. Capacity of reservoir, 3,751,791,436 cubic feet. Area of reservoir surface, 658,209,024 square feet. Area of basin 4,990,223,600 square feet. To cost $75,334. This dam will probably pond the water up close to the foot of Vermillion dam. This dam can only be raised to a height of 7 feet above the stage of water of 1874; if raised to a greater height, there would be danger of the ponded up water in Pokegama Lake flanking the dam and finding egress through the depression, and across the sand ridge near the end of the southeast arm of the lake. This is fully described in the report of February 4, 1875, and can be appreciated by an inspection of the maps.

6. *Dam at Pine River.*—To cost $32,386.20. Major Farquhar says of this dam:

> A good storage-ground for water was found on the Pine River (see Detail Map No. 3). Pine River runs through a series of connecting lakes. Just below Cross Lake there is a good place to build a dam. The watershed above the outlet of Cross Lake has an area of 551 square miles. Estimating the annual rainfall at 25 inches, and that 8½ can be relied upon, there will result a total discharge per year of 10,752,698,880 cubic feet. The banks of the lakes are generally high, and have a surface area of 491,301,043 square feet. If it were desirable to hold all the above water, it would require a dam 24 feet high, but from present information it would not be practicable to construct so high a dam. An additional dam at the mouth of Whitefish Lake might be constructed, 20 feet high, and the other at the outlet of Cross Lake, 12 feet high. The latter dam would create a reservoir of 4,913,000,000 cubic feet capacity, which, during the low-water season of the Mississippi River, August, September, and October, would furnish 630 cubic feet per second.

7. *Gull Lake Dam.*—To cost $25,786.20. Of this, the same officer reports:

> The system of lakes, of which Gull Lake is the center (see Detail Map No. 2), and which discharge their waters into the Crow-Wing River through the Gull Lake River,

form an excellent storage for water. The discharge of Gull Lake River was, on the 10th of November last, 330 feet per second. The area of the water-shed of the Gull River above the outlet of Gull Lake, is 7,582,924,800 square feet, and assuming that one-third of the annual rainfall can be collected in the reservoirs and discharged therefrom, we would have 5,262,920,000 cubic feet. The area of Gull and adjacent lakes that can be used for storage purpose, is 501,841,200 square feet, on which the water can be stored for an average depth of 10 feet, and 223,027,200 square feet on which an average depth of 5 feet can be stored, giving a total capacity of 6,133,548,000 cubic feet. A dam 12 feet high can be easily constructed to obtain the above capacity of reservoir.

Having determined the area of water-sheds, areas of reservoir surfaces, and the capacities of reservoirs, the next step was to deduce the available amount of water, or the supply. In this calculation two methods were employed.

The first consisted in assuming, from an examination of all the records of rainfall at points bordering or within the watershed, a mean annual precipitation. (Tables of rainfall are appended.) The mean annual rainfall for the sources of the Mississippi was assumed at 25 inches, and, for the available quantity, that which actually finds its way into the streams, 0.7 foot was assumed, a figure that must certainly lie within the limits of safety. The area of water-shed tributary to the river at Pokegama Falls being 102,174,325,600 square feet, the product of this by 0.7 foot would be 71,522,027,920 cubic feet, a quantity equivalent to a flow of about 6,800 cubic feet per second or 120 days.

In the second method of computation, we assumed the reservoirs to be completely closed from December to July 1, before the low-water period could set in. The measured low-water discharge for the months of December, January, February, and March is then supposed to be impounded. Three-fourths of the mean precipitation (rain and snow) is then added, it being supposed that, on account of the ground being frozen, at least that quantity will flow into the reservoir; and, finally, one-half of the rainfall during April, May, and June. These all added together will give the quantity on hand July 1.

The results from these two methods can be seen by inspection of the following table.

These methods, I should add, have only been applied to the five reservoirs spoken of at the headwaters of the Mississippi. For the Gull Lake and Pine River reservoirs the figures are taken from the report of 1875.

Locality.	Height above reduced stage of 1874.	Length of dam.	Area of basin.	Area of reservoir.	Capacity of reservoir.	Supply in cubic feet.	
						First method.	Second method.
	Feet.	*Feet.*	*Square feet.*	*Square feet.*	*Cubic feet.*		
Winnebigoshish	14	1, 114	52, 745, 932, 800	4, 312, 701, 360	45, 754, 204, 380	36, 922, 152, 960	37, 773, 739, 008
Leech Lake	4	3, 300	27, 906, 278, 400	6, 091, 430, 400	22, 567, 564, 800	19, 534, 394, 880	15, 460, 977, 021
Mud Lake	6	1, 000	4, 460, 544, 000	480, 902, 400	2, 885, 414, 400	3, 122, 380, 800	3, 137, 885, 040
Vermillion	10	2, 300	12, 071, 346, 800	961, 804, 800	5, 770, 828, 800	8, 449, 942, 760	8, 562, 762, 188
Pokegama	7	400	4, 990, 223, 600	658, 209, 024	3, 751, 791, 436	3, 493, 156, 520	5, 117, 636, 396
Total	......	......	102, 174, 325, 600	12, 505, 047, 984	80, 729, 803, 816	71, 522, 027, 920	70, 052, 999, 653
Add to this from dams at--							
Gull Lake	12	450	7, 582, 924, 800	724, 868, 400	6, 133, 548, 000	5, 265, 920, 000	....
Pine River	12	600	15, 360, 998, 400	....	4, 913, 000, 000	10, 667, 353, 750	....

Both methods of calculation show a surplus for Mud Lake and Vermillion reservoirs. By the second method a total surplus is carried to the Pokegama reservoir of 4,247,778,348 cubic feet, or, per second, 548 cubic feet to be discharged from the latter reservoir. It will also be seen from the table that Pine River reservoir will furnish a large surplus. We have in round numbers from the reservoirs for Winnebigoshish, Leech Lake, Mud Lake, Vermillion Biver, and Pokegama, 70,000,000,000 cubic feet.*

Leech Lake reservoir is tributary to that at Mud Lake and to that at Vermillion. Winnebigoshish is also tributary to Vermillion, and the last tributary to the Pokegama reservoir, which becomes, consequently, the distributing reservoir above Aitken.

Low-water occurring after the 1st of July, seldom before the 15th, we have from this supply—neglecting the 548 cubic feet per second of surplus water flowing on the Pokegama dam, for a period of 120 days, leading us into the middle of November, by which time navigation on the river above Hastings generally begins to close—6,750 cubic feet per second.

Two questions arise here:

1st. Will there be channel capacity to enable this impounded water to flow from reservoir to reservoir, and from the lowest reservoir down the Mississippi above Brainerd?

2d. Will the impounding of the water previous to July 1, injuriously affect the navigation of the river above Aitken and Brainerd before any supply is drawn off from the reservoirs? the navigation from Brainerd to Aitken, and particularly from the latter place to Grand Rapids, 3 miles below the Falls of Pokegama, being of importance, as the lumber camps are largely supplied by steamers plying to Grand Rapids.

As regards the first question, the Pokegama reservoir being the distributing one we should expect, when needed, the full discharge per second through the dam (a needle-dam is under consideration at this point). The dam rising to a height of 7 feet above the high-water of 1874, at which time there was a depth of 4 feet of water at the dam site, with hard rock bottom, the fall below the dam being 14 feet on a distance of about 900 feet, no trouble is anticipated in discharging the necessary quantity of water per second. Of course, as the surface of water in the reservoir lowers, toward the latter part of the season, the flow will be diminished. The Pokegama reservoir will have to be constantly supplied from that at Vermillion. The width of the dam at the latter place is sufficient to provide for the discharge.

A glance at the map will show that there is ample space for the water to move from Vermillion to Pokegama, for the least area of flood-section between these points would be 3,500 square feet.

Above Vermillion there will be required channel capacity for 6,750 cubic feet per second from the junction of Leech Lake River. The narrowest part of the flooded channel would be just below the junction of the Leech Lake and Mississippi Rivers, where not more than 600 feet in width can be obtained for a distance of about a mile. A sounded cross-section taken here in 1874, where the stream was just within banks, and 170 feet to 200 feet in width, gave an area of cross-section of 1,200

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*If we make a further reduction, by regarding the evaporation from the surfaces of the reservoirs as equal to the entire rainfall of the basin, we have $12{,}505{,}047{,}984 \times 0.7$ foot (we have already subtracted $2.083 - 0.700 = 1.383$ from the rainfall), $=$ 8,753,533,588 cubic feet, which, deducted from the 70,000,000,000, leaves us about 7,100 cubic feet per second for a period of 100 days. But it is thought that in taking 0.7 foot as the available rainfall over the entire basin, enough reduction has been made.

square feet. A rise of 2 feet above the surface of the river at that point would add 1,200 square feet to the cross-section, ample for a discharge of 6,750 cubic feet. The fall, in 1874, from the junction to White-Oak Point, a distance of 15 miles, was 3.6 feet. The loss of head, on this distance, from bend effect, might rise as high as 1 foot, leaving 2.6 feet available fall over this distance; but, as the surface of water rises, we may look for an increase in the mean velocity, the distance between the points, for the flow of water, being shortened. After leaving this narrow portion of the river the valley widens out and we enter a broad savannah.

Above the junction of Leech Lake River with the Mississippi the supply will come from two sources, viz, from Leech and Mud Lake reservoirs, and from the Lake Winnebigoshish. Dividing the 6,750 cubic feet, we have about 3,400 cubic feet to be drawn at times from each source. By reference to the maps and sections it will be seen that ample channel capacity exists. The management is a matter of detail. This is under the supposition of a systematic working of all the dams so as to keep the Vermillion and Pokegama reservoirs full. If it should be decided to build the dam at Winnebigoshish in order to test the effect upon navigation, it would probably be necessary to draw 6,000 to 7,000 cubic feet per second from it, for which sufficient channel capacity exists, as can be seen from the maps and sections. The swell, or backwater, produced by the dams, has not been considered further than to regard the surface of the water ponded up as a level surface. The data at hand are insufficient to allow of such calculations.

As regards the dam at Pokegama, Major Fahrquar reports (see report of 1875):

> At Pokegama Falls it is proposed to put in a needle-dam on the left chute, at the head of the falls, and a solid masonry weir over the other (see detail map). By blasting out the head of the ledge, a greater aperture of discharge can be gained.

The channel below Pokegama Falls has sufficient capacity. Its width from Pokegama to Brainerd was, in 1874, seldom less than 200 feet; at Grand Rapids it was only 130 feet, but here the fall was 5 feet in 1,750 feet of distance. At Sandy Lake River, 86 miles below Grand Rapids, the discharge was October 27, 1874, 2,950 cubic feet per second, the gauge at Aitken, 61 miles below, being 3.8 feet above low-water. Below Willow River, 39 miles below Sandy Lake River, the measured discharge on the 3d of November, 1874, was 3,784 cubic feet, the gauge at Aitken showing a stage of water of 3.3 feet. The Aitken gauge has shown a stage of 10 feet. A measured discharge at Brainerd June 4, 1875, showed 13,500 cubic feet per second as the quantity of water passing that point, and the gauge at the same place has indicated a higher stage of water. When we add to this the fact that from Pokegama Falls to Brainerd, the latter at the crossing of the Mississippi River by the Northern Pacific Railroad, the banks rise from 8 feet to 10 feet above low-water, all doubt as to the capacity of the channel to both carry off the necessary quantity of water and to retain ordinary flood discharges may be dismissed. The removal of bowlders from the channels above and below Pokegama Falls would, doubtless, facilitate the flow, and, below the falls, aid the navigation materially. It is possible that siphons, especially at the Winnebigoshish dam, properly constructed and built into the dam, would take the place of a portion of the gates and sluices.

As regards the second question:

The area of watershed tributary to the river above Aitken is 2,500 square miles. Assuming the same coefficient that we did in making our calculations for supply by the first method, and applying it to the mean precipitation for the months of April, May, and June, we have a quantity of water passing Aitken equivalent to 2,005 cubic feet per second; adding to this the surplus from the Pokegama reservoir, we obtain a total of 2,553 cubic feet per second. And, taking further the available amount of rainfall and snow for the months of December, January, February, and March at 2 inches, a safe figure, we have a quantity of water equivalent to 3,300 cubic feet per second, round numbers, passing Aitken. This flow, as it approaches Brainerd, is re-enforced by the contributions from the watershed below Aitken. Good navigation obtains above Brainerd, where the flow per second equals 3,000 cubic feet, excepting where some few natural obstructions exist. Of course, as we proceed from Aitken to Grand Rapids above, the area of watershed tributary to the portion of the stream decreases until we reach a point where the supply may become too small, requiring us to draw off from the reservoir 1,000 to 1,500 cubic feet per second for a time. But, as before said, we can spare from the reservoirs during April, May, and June the 548 cubic feet per second which we should have to count as surplus water after July 1. Assistant Skinner reports upon this as follows:

Now, it is believed that the lower river, above Aitken, can take care of itself before July 1, as its watershed is upwards of 2,500 square miles and its affluents numerous; but let us suppose the worst case possible, viz, that after May 1, the earliest date that navigation ever begins, we have to supply the lower river as far as Aitken. We know from careful observations in 1874 that 2,500 cubic feet per second, discharged at Pokegama Falls, gives excellent navigation as far as Aitken, and, it is to be presumed, for a much greater distance down, as the river is deep, except in a few instances where obstructions, such as small rapids, &c., exist, to below the mouth of the Crow Wing River.

Now, from May 1 to November 1, 6 months or 180 days, will require, at 2,500 feet per second, in round numbers, about 37,500,000,000 cubic feet, leaving us with 32,500,000,000 cubic feet in store to supply the lower river in addition for a period of 120 days, from July 1 to November 1, which gives us 3,135 feet per second. But we have, further, a constant supply from Pine and Gull Lake Rivers, as shown by the surveys of 1874 (see Colonel Farquhar's report, 1875), of 1,062 feet per second, which, being added, gives us a total supply of 4,197 cubic feet per second, and this while 2,500 cubic feet per second was being added to all the resources of the river below Pokegama Falls. Mille Lacs might possibly furnish a small further supply, but I do not think it safe to count it. Further, in the case under consideration, were the dams opened on May 1, in order to supply the 2,500 cubic feet, there would be no surplus, as it would not have collected. We are, therefore, entitled to add the amount of that surplus, viz, 547 cubic feet, which gives us a total of 4,744 cubic feet per second. Now from accurate gauging in 1875 of the Mississippi River above the Falls of Saint Anthony, and the Minnesota River at its mouth, we know that we can set the low-water discharge at Saint Paul at 5,800 cubic feet per second. Now, we can add to this 4,744 cubic feet from the reservoirs, making a total amount passing Saint Paul, at extreme low-water, of 10,544 cubic feet per second. It must be borne in mind that the case supposed on which these estimates are based can never occur, as the river below the falls and above Aitken must always have some water running. I think it would be perfectly safe to add one-half of the amount allowed (2,500 cubic feet per second) to the foregoing estimate. We would then have—

	Cubic feet.
Former amount	4,744
Added amount	1,250
Total amount furnished at Saint Paul	5,994
Low-water discharge at Saint Paul	5,800
Total amount per second passing Saint Paul, low-water	11,794

There is still further reason, amounting almost to a certainty, for the belief that the Mississippi River below Pokegama Falls can be supplied, from its own watershed, with ample water for all purposes of navigation prior to July 1, and it is absolutely certain that before that time the river below Aitken is entirely independent of the discharge at Pokegama. The character of the two districts is entirely different. Above the falls, the whole country is, in a certain sense, a reservoir. It receives and retains vast quantities of water, which drain off slowly. Large lakes, with very slight differences of level and immense marshes bordering them, retain the waters from the higher portions of the basin and part with them slowly.

There are no freshets, no sudden rise or fall in the surface of the lakes or streams. All changes are so gradual as to be scarcely perceptible. The extreme range of Leech Lake is only 1.7 feet, and this is only the gradual change from a very wet season to a very dry one, and is due largely to evaporation. A reference to the general map, on file in Washington, will show the character of the region, and it will be seen from the sheets of gauge-readings, hereto attached, that at and above Grand Rapids the gauge curve is practically an unbroken line. Below Grand Rapids the whole country is different. The river becomes a true river with defined banks, and is fed by numerous tributaries, while above there are only a few small streams that lose themselves in swamps before they join the river. Three miles below Grand Rapids is Prairie River, a rapid stream which, at times of high-water, discharges large volumes, and is subject to freshets. It produces such an effect on the river at Grand Rapids, that, when the gauge above the falls showed a steady decline, the gauge at the foot of Grand Rapids has been known to mark a rise of a foot.

The Split Hand, Wild Swan, Sandy Lake, Rice, Mud, and Willow Rivers, are important tributaries. This last drains a very large area, as will be seen from the map. A reference to the gauge-readings, and comparison of the curves above and below, will show plainly the wide difference in the character of the two portions of the river. The upper are almost unvarying; the lower subject to sudden changes. As to the date set, July 1, it is not too much to say that low-water has never occurred at or before that time. It will be seen, by reference to Table A, that May and June have the largest mean rainfall. It is, besides, universally known as the high-water month. A decline to low-water by the 1st of July is almost impossible. It has, at least, never occurred. We have a fair right, therefore, to conclude that July 1 will never find the upper river without sufficient water for purposes of navigation.

There is only one place at which any continuous record of gauge-readings has been kept in this district, and that is at Saint Paul, where the Signal Service records extend over a period of 7 years, from 1872 to 1878, and this includes some years of very low water, and the highest does not reach midway the range between high and low water. The mean reading for July 1 is 6 feet 2 inches above low-water, while the gauge at Aitken on July 15 was 7½ feet above low-water of 1874. We have before said that the area of the watershed below Pokegama Falls and above Aitken is 2,500 square miles. Now, using the second method of computation before described, which, comparisons given would seem to establish as just, this will furnish at Aitken, continuously, up to July 1, 4,362 cubic feet per second, while, in 1874, a discharge (measured) at the same place, of 3,088 feet per second, gave much more than the necessary depth of water required for navigation. It would seem, then, that it is abundantly established that we can shut off the entire river above Pokegama Falls up to July 1, without interfering with navigation below. But, in that case, we should have a surplus of 547 cubic feet per second to be added to the volume below, which would enable us to add 1,250 cubic feet per second to the last amount before given as passing Saint Paul, viz, 11,794 cubic feet per second, making the total amount 13,044 cubic feet per second, or, deducting the low-water flow at Saint Paul, 5,800 cubic feet per second, we can supply from the reservoirs above Pokegama Falls 7,244 feet per second, for a period of 120 days after July 1.

The past season has been one of unusually low water; many of the smaller streams almost dry. It may take an unusually wet season to establish a favorable order of affairs at the sources, supposing the reservoirs to be created. A measurement of the discharge past Saint Paul, in October last, gave 6,150 cubic feet per second. In this discharge, as n previous low-water measurements at the Falls of St. Anthony, must be included the contributions from the upper river past Pokegama Falls, and from Pine and Gull Rivers, the former, as already stated, however, being able to furnish a surplus from its reservoir.

Taking into consideration all the items of diminution of supply, it seems clear that a discharge of 12,500 cubic feet, at least, can be maintained past Saint Paul for a period of 100 days. There is no doubt that good navigation exists in all the navigable reaches above the Falls of Saint Anthony, where the discharge at the falls is from 11,000 to 12,000 cubic feet per second. An increment of 6,500 to 7,000 cubic feet per second cannot fail to prove of benefit to navigation between Saint

Paul and Hastings, and, if so, the outlay for the creation of reservoirs will be amply returned. As the quantity of water at and below Saint Paul is increased from sources below Pokegama, the increment from the reservoirs will, of course, add to the beneficial effect until a certain limit is reached, when the proportion of the increment to the whole will be too small for the increment to be appreciated. When this limit is reached, the dams can be shut and the accumulation of water will go on.

The mean discharge of the Mississippi past Saint Louis is 225,000 cubic feet per second. To those who are only accustomed to dealing with such large volumes of water, an increase of 7,000 cubic feet per second appears very small. Yet, beyond a certain limit, width of channel is of small importance to light-draught steamers, depth being then the most important factor so far as navigation is concerned.

There can be no doubt that the control of the flow past Pokegama would render unnecessary many of the jetties and wing-dams between that point and Minneapolis, an estimate of cost of which is contained in the report of February 8, above alluded to.

The total cost of constructing the dams for creating reservoirs at the sources of the Mississippi is $336,458.60, an amount which includes contingencies of engineering, &c.

The cost of maintenance, understanding by this the repairs, would not, probably, exceed $10,000 per annum for the entire system for the first 10 years.

The cost of operating each dam would probably be as follows:

One dam-tender, at $800 per annum; 2 laborers, at $40 per month, each, for 4 months in the year, $320, or, in all, $1,120 per annum for each dam, and $7,840 per annum for the entire system.

To operate the entire system to best advantage the reservoirs would have to come within telegraphic communication. The probable cost of telegraph lines, starting from stations on the Northern Pacific Railroad, would be $13,500, this sum including batteries, &c. The operators could act as dam-tenders and also keep meteorological records.

The damage to property would consist, so far as can be ascertained, in the overflow of hay-meadows, of small value, and the overflow of fields of wild rice upon which the Indians depend, but these latter would, as the adjoining lands come under the influence of the prolonged rise of water, be simply transferred. From the best information attainable at present, I do not think that more than 2,500 acres of entered land would be overflowed, though this estimate is held subject to revision. The land at present is of little value. It is possible, though, that the prospect of the erection of dams, developing the water-power, may cause some of the adjoining lands to be held at a high figure.

The distance from Saint Paul to Pokegama is 350 miles. If the water be drawn off from the Pokegama reservoir at too late a moment it will be some days before any good effect can be felt at Saint Paul. By means of telegraphic communication, and a proper system of gauges, the date at which the gates should be opened can be predicted.

It has been claimed by those opposed to the reservoir system that the additional water discharged from the reservoirs will evaporate before it can reach Saint Paul. It hardly seems worth the while to reply, yet, perhaps, they are entitled to one. The rate of evaporation is directly as the area of surface exposed. If the surface be disturbed or corrugated from any cause, of course the area is increased. If the increment of water does not result in increasing the width of river surface, no more evaporation will result than would before any increase in volume obtained. And we have, during the time that the lower river is receiving this increment, the usual amount of rainfall below Pokegama. This question of loss by evaporation may be dismissed.

The lakes at the source of the Mississippi furnish a compact reservoir system, almost as if laid out by an engineer.

I think that it would be well worth the expense to test the efficacy of a system by constructing the dam at Lake Winnebigoshish, for which an appropriation, made in bulk, of $70,000, would be necessary. This sum is named because in building only one of the system, the expense of building and testing the effect will be greater, relatively, than if all were to be built. Should this dam be built, as a test, no prolonged benefits to navigation ought to be expected from a solitary reservoir.

No estimate is submitted herewith for locks in order to pass these dams, as full data are not at hand, and besides there is nothing at present, beyond canoe navigation, above Pokegama, if we except a small steamer that is plied on Leech Lake. Log-chutes will have to be provided for. Time has not admitted of making any detailed drawings of the proposed dams, or of revising any heretofore made. Timber is easily accessible, and rock in place is found at Pokegama. Scattering bowlders exist in the beds of the streams.

The immediate examinations were made by Mr. John McCalman, assistant engineer, assisted by Mr. Rufus Davenport, assistant engineer, both of whom are entitled to credit for faithful and zealous performance of duty.

EXAMINATION OF THE SOURCES OF THE SAINT CROIX.

The party engaged in examining the sources of this stream was under the charge of Mr. H. S. Treherne, assistant engineer, assisted by Mr. George R. Stunz and Mr. M. L. Lum, assistant engineers. The work was well done. The party proceeded, via Taylor's Falls, to the Upper Lake Saint Croix, reconnoitering the country on the way. The Upper Saint Croix was thoroughly examined. Thence the party moved to the Totogatic, and finally closed operations for the season by an examination of Yellow River and its basin. Permanent bench-marks were left for future reference, the flow of the streams gauged, and such observations for rainfall and evaporation made as allowed of. A large amount of information was collected, which cannot, at present, be utilized. The party to gauge the discharge of the Saint Croix from the Namakagon to Taylor's Falls, under Mr. W. H. Fuller, assistant engineer, assisted by Mr. James Allard, took the field about the 1st of October. The Eau Claire, Clam, and Namakagon, the latter the principal affluent from the east, and the Snake and Kettle Rivers from the west, both large affluents, require thorough examination, as does also the valley tributary to that portion of the main stream below Taylor's Falls. In fact, the river from Taylor's Falls to the mouth should be thoroughly surveyed, the survey made some years ago having been, from lack of means, incomplete. The need of such a survey, as well as its cost, together with a statement of the features of this portion of the stream and the improvements needed, are given in my report dated December 9, 1878.

For a description of the country examined, I would, respectfully refer to the report of Assistant Skinner. Extensive lumbering operations are carried on throughout the whole valley of the Saint Croix, and from Taylor's Falls, the head of navigation, to the junction of the river with the Mississippi, several steamers run daily. The tributaries above Taylor's Falls are encumbered by large dams for logging purposes. The "drive" of logs through the Dalles, and thence down to the booming grounds above Stillwater, in May and June is so great as frequently to shut the steamers completely out.

As the result of our examinations, three sites for dams have been selected and the capacities of the reservoirs ascertained, viz, one about a mile below what is known as the "Big Dam," on the Upper Saint Croix River, one on the Totogatic, and one on the Yellow River, below the outlet of Yellow Lake.

The Upper Saint Croix Lake reservoir has a surface area of 459,792,500 square feet, the capacity being 4,698,269,800 cubic feet, the dam to be 25 feet in height; the area of basin from which the supply is drawn being 8,084,739,000 square feet. The available supply, assuming 25 inches as the rainfall, and taking one-third of it as available, will be 5,659,315,200 cubic feet, leaving a surplus of 961,045,400 cubic feet, which can probably be retained by a dam at some other point.

The Totogatic reservoir has a watershed of 9,199,872,000 square feet, giving as available supply 6,439,910,400 cubic feet. The capacity of reservoir being only 2,881,095,000 cubic feet, we have a surplus of 3,558,815,400 cubic feet, which can probably be retained by means of another dam, yet to be located. Yellow Lake reservoir has a watershed of 8,962,905,600 square feet, furnishing as an available supply 6,274,033,920 cubic feet. The reservoir capacity being only 3,402,712,000 cubic feet, we have a surplus of 2,871,321,920 cubic feet.

The summation can be stated as follows: From the three reservoirs already located, we can deliver to the river below Taylor's Falls, in the interest of navigation, 1,412 cubic feet for a period of 90 days, and, could we retain the surplus, we could furnish for that period a total of 2,362 cubic feet per second. It must be borne in mind that five considerable affluents yet remain unexamined, so that it is not possible as yet to hazard an opinion as to the practicability of aiding navigation on this stream or the Mississippi by means of reservoirs.

A lock and dam at Prescott, for the double purpose of benefiting the navigation of the river below the falls, and to create a huge reservoir, instead of many smaller ones, have been frequently suggested. This would undoubtedly reduce the time and cost of surveys, and simplify the problem, but to what extent it would benefit the interests of the valley, I am unable at present to state.

We have assumed in our calculations the value of the rainfall as 25 inches, and taken one-third of it as a factor, as the watershed lies partly in Minnesota. We have not yet been able to determine with sufficient precision the value of either.

The total area of watershed above the Dalles (Taylor's Falls) is about 6,000 square miles, for which, if we assume 10 inches as the available amount of rainfall, we have passing the Dalles, for the entire year, a quantity equivalent to a mean flow of about 4,500 cubic feet per second; to this must be added the quantity feeding the navigable portion of the stream, below Taylor's Falls, from the watershed (about 1,600 square miles) tributary to this portion. During the past season 3 feet of depth existed on the bars when the quantity of water passing the Dalles was 3,500 cubic feet per second. It is safe to say that good navigation will be found when 4,000 feet of water pass the Dalles; a steady flow of 5,000 cubic feet per second from this stream into the Mississippi River could not fail to aid the navigation of the latter for many miles below, especially when joined to a steady flow of 12,000 to 13,000 cubic feet past Saint Paul.

A plotting of gauge readings at Taylor's Falls, Osceola, and Stillwater, and of soundings on the principal bars between the latter point and Taylor's Falls, covering the same period as the gauge readings, herewith submitted, shows the relation that existed, during the low-water season of 1878, between the stage of water and the depths on bars and crossings; it also shows that the bed of the river changes. The fluctuations of water surface, as indicated by the gauge curves, are mainly due to the opening and closing of the large dams on the tributaries above.

EXAMINATION OF THE SOURCES OF THE CHIPPEWA.

This is a difficult region to survey for sites of reservoirs, the country being so cut up by small streams and interspersed with lakes, the latter sometimes forming, apparently, independent systems unconnected by streams.

The Chippewa rises among the small streams and lakes along the south side of the ridge, dividing its watershed from that of the streams flowing into Lake Superior. The principal tributary is the Flambeau, coming in from the northeast and uniting with the Chippewa above a point known as Flambeau Farms. The Flambeau, having much the larger volume of the two forks, ought to give its name to the whole stream. From the Flambeau down to Chippewa Falls the stream is known as the Wild Chippewa, from the number of rapids, bars, &c. The stream below Chippewa Falls is described in the report of Major Farquhar of January 30, 1875, and also in my own report of December 28, 1878. The needs of navigation and the damage resulting from the unsystematic workings of the dams on the river and tributaries above Chippewa Falls are fully set forth in those reports. The Court Oreilles, an important tributary, flows in from the west above Chippewa Falls, as does the Yellow River from the east. Besides, there are a number of smaller tributaries, all of which are used, more or less, for hegging purpose.

The area of watershed above the junction of the Flambeau and Chippewa is about 3,761 square miles, but, on account of the formation of the country, the narrow valleys through which many of the streams flow for long distances, with heavy slopes, &c., only a portion of this watershed becomes available, as the choice of sites for dams becomes thereby limited. Dams of great height can be thrown across the narrow valleys to pond up above each a few days' supply of water, but the benefits to result therefrom would not warrant the expenditure of money.

The party for the examination of the sources of this river was in charge of Mr. J. H. Daga, assistant engineer, assisted by R. T. Parker and W. W. Strong, assistant engineers. The latter soon left the party, and the force was increased by Assistants W. W. Redfield and G. O. Foss. The party proceeded by rail to Fifield, on the Wisconsin Central Railroad, and thence to an examination of the watershed of the Flambeau. The details of work and description of the country are to be found in the appended report, and can be seen by inspection of the maps. The party, after finishing the Flambeau, was to cross to the headwaters of the Tomahawk, an important tributary to the Wisconsin, which they were expected to reach early in October. They did not reach this ground, however, until the middle of November—a severe disappointment to me. I immediately reorganized the party for the survey of the

Tomahawk. The area of watershed above the junction of the Flambeau and Chippewa is—

	Square miles.
Of the Flambeau	1,960
Of the West Fork of the Chippewa	1,801
Total	3,761

but the available water-shed of the former is only 712 square miles, and of the latter 700 square miles; a total of 1,412 square miles.

Three dams and reservoirs were located. The first, at Butternut Lake, has a drainage area of 1,533,312,000 square feet, affording a supply of 1,272,648,960 cubic feet, assuming that 10 inches of rainfall can be made available; the dam to be 10 feet high. The capacity of reservoir 585,446,400 cubic feet; leaving a surplus of 687,202,560 cubic feet. This reservoir possesses little value.

The next at Park Lake, just above the 30-foot falls on Turtle River. The area of its watershed is 4,850,841,600 square feet; affording, on a basis of 10 inches, 4,026,198,428 cubic feet. The capacity, with a 15-foot dam, is 620,782,720 cubic feet; leaving a surplus of 3,405,415,708 cubic feet.

Rest Lake Reservoir, the next to be created by a dam 25 feet high, will have a capacity of 5,661,462,400 cubic feet; the supply being 4,897,100,264 cubic feet.

The result of the examinations thus far, covering only a very small portion of the basin, shows that there can be supplied from the north fork of the Flambeau alone 887 cubic feet of water, for a period of 90 days, per second; while, could the surplus be retained, 1,412 cubic feet per second could be maintained.

Below Chippewa Falls are important tributaries also, viz, the Eau Claire, the Menomonie, and Eau Galle, from which additional supplies can probably be drawn, although the Eau Claire and Menomonie are controlled by private parties, as seems to be the case with many of the streams in Wisconsin and the eastern slope of Minnesota above Taylor's Falls.

The drainage area of the basin above Chippewa Falls is about 5,600 square miles; the total area drained by the river being about 9,600 square miles. Assuming 10 inches as the available rain-fall, we should have, for the area above Chippewa Falls, a volume corresponding to a mean flow of, per second, about 4,125 cubic feet; and adding to this the supply tributary to the river below, we should have a volume corresponding to a flow of 7,060 cubic feet per second through the jetties at the mouth. The area of watershed for the entire river, here given, is taken from the report upon bridging the Mississippi River.

From observations during the past season it would appear that when 3,200 cubic feet per second pass Eau Claire and 4,500 cubic feet per second pass between the jetties, a navigation of 3 feet on the bars and crossings can be generally maintained, although from the shifting nature of the bed and banks defensive works, jetties, &c., will probably be required in addition to a steady flow, supposing that the latter can be maintained. Beef Slough, about 20 miles above the mouth, draws off largely from the supply going to the jetties. To close the entrance to the slough would undoubtedly benefit navigation between this point and the mouth of the river, but it would injure the Beef Slough Company, which company use the slough for booming grounds. Any water diverted from the slough through the jetties would add to the quantity passing down the Mississippi from the jetties to the mouth of Beef Slough, of course not adding any quantity to the Mississippi below the mouth of the slough. As to the propriety of closing the entrance to the slough, much may be said pro and con. Navigation would be benefited by such a course. The slough, about 35 miles in length, is a mass of sand bars and banks, between and among which a considerable volume of water finds its way, ultimately discharging into the Mississippi River about 10 miles below the Chippewa. Much of the sand is undoubtedly carried into the Mississippi. The protection of the Yellow Banks on the Chippewa River, referred to in my report of December 28, would arrest, in a great measure, the movement of sand down that stream, and probably affect the supply going to the slough, but to what extent further study and examination must determine.

A plotting of 12 sounded areas, the soundings taken on 4 consecutive days on 3 cross-sections, the latter 100 feet apart between the jetties, shows to some extent the movement of sand, &c., forming the bed, and a plotting of synchronous gauge-readings at Eau Claire and the mouth shows fluctuations of water-surface mostly due to the working of the dams.

It is not assumed that any extensive deductions can follow the observations on the Chippewa and Saint Croix for a single season; but the system of observations begun will, if carried out thoroughly, afford the means of drawing up, intelligently, plans for the improvement of the streams.

A continuous survey of the river from Chippewa Falls to the mouth, independently of the examination of the sources, is desirable.

EXAMINATION OF THE SOURCES OF THE WISCONSIN.

The party for the survey of the sources of this river was placed in charge of Assistant Wanzer, who, assisted by Mr. R. T. Parker, completed the survey of the Tomahawk Basin in about 22 days, locating two dam sites, and obtaining, otherwise, information of value.

Below the Tomahawk there seems to be no suitable sites for reservoirs, if we may rely upon information thus far obtained. Two good sites are reported for dams which will control the whole watershed above the mouth of Pelican River, the drainage area being 830 square miles, the reservoirs estimated to control 2,470 cubic feet per second for a period of 90 days. Of these two sites, Assistant Skinner says:

> Two dams have already been erected, one first above the mouth of Pelican River, and another 30 miles above, below the mouth of Eagle River, at a point which is known as Otter Rapids. The first has a watershed of 444 square miles, the latter one of 386. The data that I have been able to obtain as to the operations of these dams are as follows: The upper, or Otter dam, has raised the water above it to a height of 4 feet above ordinary level. I am informed that it can easily be raised 12 feet. The lower, or Pelican dam, allows of a rise of 9 feet, and can be also raised so as to admit of 12 feet. This last dam, when the water is raised 9 feet, backs up the water 22 miles, or within 8 miles of the Otter dam. The upper reservoir, with 4 feet head, when the gates are opened, requires from a week to ten days to empty itself. When it has discharged its contents into the Pelican dam, below, the latter reservoir is raised to a height of 8 feet 10 inches, and when the gates of this are opened, a rise of 4 feet at Jenny, 65 miles below, and a rise of 3 feet at Warsaw, another 65 miles farther down, ensues. These are the facts given me by the lumbermen.

Of the dams on the Tomahawk, the first or upper dam, to be 18 feet in height, will form a reservoir of 2,000,000,000 cubic feet capacity, the area of basin being 200 square miles, which, with an available supply of 10 inches from rainfall, will give 4,627,714,400 cubic feet, and a surplus of 2,627,714,400 cubic feet. The second or lower dam, to be 14 feet high, will afford a reservoir capacity of 1,043,516,880 cubic feet, the area of watershed being 380 square miles, and the supply 8,792,847,360 cubic feet, giving a surplus of 7,749,330,480 cubic feet, which cannot, probably, be collected at any point below. We have, then, as this supposition, the control of only 391 cubic feet per second for 90 days from the reservoirs on the Tomahawk.

So large an area of the watershed of the Wisconsin above Warsaw yet remains to be examined that it is not possible, as yet, to express any opinion as to the effect of reservoirs upon the navigation of the Wisconsin, or upon that of the Mississippi. The area of the Wisconsin River watershed is, as given by General Warren in his report upon bridging the Mississippi River, 11,850 square miles. Assuming, for this area, an available supply, from rainfall, of 10 inches per annum, we have a quantity of water corresponding to a mean flow of 8,730 cubic feet per second at the mouth of the river. The flow of water per second, corresponding to good navigation on the Wisconsin, can be given by the officer in charge of the improvement of that stream.

It is to be hoped that further survey of the sources of this river will not be impeded from lack of appropriations by Congress.

A few points suggest themselves before going further. If the water be ponded up in reservoirs, the affluents below will contribute their supplies of sand, gravel, &c., as usual; the total quantity may be decreased by that kept back above, although the quantities of water let out from the reservoir may result in erosion of the banks, and restore, perhaps increase, the quantity of sand, &c., to be dealt with. Now, by disturbing the usual flow, increasing it during the season of low water, the rate of motion of bars, &c., will be affected. The direction of the channel, especially in the Mississippi River below Saint Paul, changes from high to low water at or just preceding the latter stage, cutting out a path for itself along, in general, the lines of least resistance. At mean or tolerably high stages, the river, flowing through an alluvial bed, flattens out the bars, so that an increase in depth does not always follow a rise on the gauge. During floods, and just as they are subsiding, the river bed is in a state of disturbance; bars move, banks cave, sediment is brought in. Without going into an analysis, which would trespass too much upon the space proper for this report, it can be seen that circumspection is necessary in the projection of any plan for improvement of sand-bearing rivers.

To appreciate the subject fully, careful observation and study are required.*

The effect upon rainfall by the denudation of the country of forests and that upon the flow into the streams following increased cultivation of the ground I cannot hazard an opinion about. The weight of evidence collected by various writers upon the subject of rainfall seems to indicate that reforesting of extensive areas of country is followed by a more equable distribution of the rainfall throughout the year.

Information as to rainfall, evaporation, infiltration, &c., was sought from all authorities within reach. But as every catchment basin has its own data, observations on the ground for a period of years afford the only safe means of accumulating such information.

In order to fully carry out the investigations ordered by Congress, at least $25,000 should be appropriated for the purpose in addition to the allotment already referred to.

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* Chapter No. 4, of General Warren's report on the Wisconsin River, and the report of Major Suter on the Lower Mississippi River, dated February 18, 1875, can be read with profit.

RECAPITULATION.

For further examination of the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, the sum of $25,000.

For the construction of the dam at Lake Winnebigoshish, to test the system of reservoirs at the sources of the Mississippi and the effect upon navigation, the sum of $70,000.

I wish to acknowledge my indebtedness to the Surgeon-General of the Army for meteorological records; also, to Lieutenant Maguire, of the Corps of Engineers, for voluntary assistance rendered by him in connection with the completion of maps.

Full appendixes are forwarded concerning the Mississippi River from the sources to Saint Paul, for the reason that the examinations pertaining to this portion of the river have been sufficient to warrant a recommendation.

Accompanying this report are the following appendixes, maps, and plottings:

Report of J. D. Skinner, assistant engineer, January 1, 1879.
Report of J. P. Frizell, assistant engineer, December 20, 1878.
Copy of meteorological records from office of the Surgeon-General, United States Army.
Seventeen tracings and maps, viz: One general map of the system of dams on the Upper Mississippi and four detail maps; one general map of watersheds in Wisconsin, together with three progress maps and eight detail sheets pertaining to said watersheds.
Nine plottings of gauge-readings, soundings, &c.
In all, 29 inclosures.

Regretting that time has not admitted of my putting this report into letter shape for transmittal,

I am, very respectfully, your obedient servant,

CHAS. J. ALLEN,
Captain of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF MR. JAMES D. SKINNER, ASSISTANT ENGINEER.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Paul, Minn., January 1, 1879.

MAJOR: I have the honor to submit the following report of examinations and surveys, made by parties under my charge, in pursuance of your order of August 16, 1878.

These consisted of detailed surveys of the different dam-sites on the Upper Mississippi River above the mouth of Crow Wing River, examinations and surveys of the headwaters of the Saint Croix River and tributaries, like examinations and surveys for the headwaters of the Chippowa River, and similar work on the headwaters of the Wisconsin River.

The season at which the parties could take the field was so advanced (after the 20th of August), and the amount to be expended so small in comparison with the vast and difficult region of country to be examined, that it was impossible to cover the ground specified in the "act of Congress approved June 18, 1878."

We were therefore, confined to making all the exhaustive surveys of dam-sites and reservoirs on the three last-named rivers that were possible, and to gather such information, by examinations and inquiry from those familiar with the streams of that wild region, as we could collect.

The case was different as regards the Upper Mississippi River. There we had the ground-work of a completed survey, with a connected line of levels, made in 1874, to work from, and one party successfully finished the work assigned them.

Starting, as we did, so late in the season, in order to have accomplished much, at least four parties should have been put in the field to examine and survey the other rivers. Lack of funds, however, rendered it possible to put only two parties at work, and the longest period that either of them was able to remain in the field was two and one-half months.

The results, though meager as far as regards the completed work, are still quite as great as could have been expected, and form a good groundwork for intelligent action another season.

It must be borne in mind that the country examined was entirely new to the parties engaged, transportation most difficult and expensive, and the obstacles in the way of obtaining accurate instrumental results as great as I have ever seen in this country.

Maps, both general and detailed, of all the country examined, have been prepared, and these show all the information obtained.

The details of these surveys and the results deduced will be reported on elsewhere.

I propose to take up the districts in the order in which they have been before mentioned, and, first, the Mississippi River above Pokegama Falls. As has been before mentioned, a very complete survey was made of this whole region in 1874. A complete line of tested levels was run from the mouth of Crow Wing River, and from Brainerd, the crossing of the Mississippi River by the Northern Pacific Railroad, to Leech Lake, thence through Cass and Winnebigoshish Lakes, down the Mississippi River to the point of beginning. An accurate survey was made of all the reservoirs and rivers, showing contour and flowage lines, the fall and discharge of streams, and all the data were acquired from which to locate the system of dams, and derive the capacity of the reservoirs, and the area of their watersheds.

All of this work, with a full description of the lakes and country through which the river flows, with the supply of water to be obtained from the different reservoirs, were fully reported to Col. F. U. Farquhar, United States Engineers, and these and the results deduced from them by him are condensed and fully described in his report dated February 4, 1875, contained in the Report of the Chief of Engineers for 1875.

Full tracings of maps of all the work done were forwarded to Washington, and as these can be referred to, it will be unnecessary for me to go over this ground again. I shall therefore confine myself to describing the work done this season; recapitulating the amounts of water to be obtained from the reservoirs, and their capacity; enumerating and describing the different dam-sites; giving a comparison of the gaugings of the river; an estimate of the amount of water that can be furnished per second at Saint Paul, stating the damage done to property by overflow; and, lastly, an estimate of the cost of constructing the different dams.

Tabular statement showing amount of rainfall, details connected with each reservoir, and showing basis of calculation for each; observation on evaporation; a table of elevation above sea-level of the water surface of the Mississippi River from Cass Lake to Saint Paul; gaugings of the river in 1874 and 1878; and plotted gauge-readings for both years, are appended to this report.

DESCRIPTION OF THE WORK.

The dam-sites above Pokegama Falls were, in 1874, necessarily located upon the map after the notes had been worked up. Of those at and below the falls full detailed surveys were made, and all work done that was necessary prior to construction. The party this year, under Mr. John McCalman, assistant in charge, and Assistant R. Davenport had, as their duty, to make accurate detailed surveys of the sites on which it had been proposed to construct dams, to select the best location for the dam, and this done, to give an accurate cross-section on the lines, followed by frequent borings and soundings, to ascertain the nature of the bottom underlying the proposed dam. This work was very laborious, requiring long and numerous transit and level lines, the country so abounding in sloughs and islands of timber that were apparently the main land, that the country for miles on either side the location had to be instrumentally examined, to make sure that there were no passages back of either end of the dam, that could connect the water above the dam, when raised to the desired height, with that below. Indeed, these examinations developod the fact, which would otherwise have escaped ordinary notice, that short and low dikes will, in some cases, be necessary. The borings were made through 2-inch gas-pipe, driven as the auger descended, and specimens of the material passed through at different depths were preserved and sent to this office. This portion of the work was difficult and tedious. Field maps were made as the work progressed, and on the completion of any one survey a tracing was forwarded to this office for inspection. The results obtained were most satisfactory. Blue clay of the best quality was found to underlie all of the dam-sites, and to exist in the banks, and it is reasonably accessible for purposes of construction. The rivers were carefully gauged near each dam-site, and the water, as well as all the levels, referred to the levels of 1874, the bench-marks belonging to which were numerous along the river. These gaugings were in the close vicinity of those made in 1874, and as the water during the whole of that season was unusually high, and during this autumn as low as ever known, a good basis of comparison was afforded. A reference to the table of discharges, marked D, hereto appended, will give the differences in height of water and discharge at the points where the river was gauged. We have, what is much to be desired, the high and low water discharge of the rivers at various points from *actual* measurements which enables us to estimate the amount of water furnished by each reservoir in two different and independent ways. The first method of estimating the supply was by simply taking the area of the watershed tributary to each reservoir and multiplying it by one-third of the mean annual rainfall. This was assumed for the district under consideration at 25 inches. A glance at the table of rainfall at different points, hereto appended and marked A, will show that the mean annual rainfall at Fort Snelling, Fort Ripley, Fort Ridgeley, and Saint Paul, derived from all the records kept up to date, is 26.41 inches, while the mean observations at Forts Abercrombie and Pembina is only 17.67 inches, from which it is to be inferred that the rainfall decreases as we go towards the west. Indeed, on the Missouri River the mean is still less than on the Red River of the North, viz, 15.51 inches. Now, this district lying so much to the westward of Forst Ripley and Snelling, it would not be safe to assume more than 25 inches as the mean. The second method of computing the supply is as follows: The reservoir considered is supposed to be completely closed from December 1 to July 1, before which time very low water rarely occurs. The measured low-water flow during the months of December, January, February, and March is then taken as a factor. Three-fourths of the mean precipitation (rain and melted snow) taken from the table of monthly means, is then added, it being considered that, the ground being frozen, at least that amount finds its way into the reservoir, and finally one-half of the rainfall during April, May, and June. These three added together give the amount on hand July. 1.

The proportions above assumed have been adopted after careful examination and consultations with persons most familiar with this subject. The results from these so widely different methods agree very closely in the total amount, though in one or two instances they differ somewhat, as will be seen by a reference to the summary hereafter given.

The totals for the district above Pokegama Falls are:

	Cubic feet.
By the first method	71, 522, 027, 920
By the second method	69, 890, 548, 635
A difference of	1, 631, 479, 285

Evaporation has been allowed for only in Leech Lake; in all the others the supply from rainfall from July 1 to November 1 being more than sufficient to compensate for all losses from that source, while in the case of Leech Lake it is but half the loss by evaporation, owing to its very large surface and the very slight height to which the water can be raised. In this connection, it will be proper to refer to the observations taken for determining the amount of evaporation. These were taken daily at morning and evening. The evaporator used consisted of a double pan 6 inches in depth, so arranged that the bottom and circumference of the inner pan were always surrounded by 2 inches of water. Three of these were used: one was exposed to the direct rays of the sun, one was placed in absolute shade, and the third was sunk to the level of the water in a marsh exposed to the sun.

The readings and means derived from them are given for each pan in the table hereto appended, marked B. From these observations, though only taken during August, September, and October, it is inferred that the amount of evaporation from April 1 to November 1 will average at least one-tenth of an inch per diem.

EXAMINATIONS OF DAMS ABOVE POKEGAMA FALLS.

Before enumerating these dams, I would remark that all the details on which the results here given are based, and the calculations by which they are arrived at, will be found in the "Table of details of reservoirs," hereto attached and marked C, and descriptions of the kind of dam recommended will be given under the head of "Cost of construction of dams."

The rise of water mentioned is always to be taken as above the high-water of 1874. The table before referred to, and the accompanying detail maps, will always show what this was. These maps will also show the locations of all the dams.

LEECH LAKE DAM.

This will be 3,300 feet in length, but will be calculated for a rise of 4 feet. The water could indeed be raised 6 feet, but it would be entirely useless to do so, as its capacity at 4 feet is largely in excess of any probable supply.

	Cubic feet.
Capacity at 4 feet rise	22, 567, 564, 800
Supply by first method	19 534, 394, 880
Supply by second method	15, 460, 977, 021

MUD LAKE DAM.

This is of moderate length, its length on top being less than 1,000 feet, and will be easy to construct.

	Cubic feet.
The capacity, with a rise of 6 feet, will be	2,885,414,400
Supply by first method	3,122,380,800
Supply by second method	3,137,855,040
Surplus by first method	246,966,400
Surplus by second method	252,440,640

NOTE.—This surplus is counted in total surplus for Vermillion Dam.

LAKE WINNEBIGOSHISH DAM.

This is the dam of the principal reservoir. It is 1,114 feet long, and is calculated for a rise of 14 feet.

	Cubic feet.
Capacity at 14 feet	45,754,204,380
Supply by first method	36,922,152,960
Supply by second method	37,773,739,000

leaving ample room for unusually high water. To raise or lower the surface, when the reservoir is filled, one foot, will require 4,312,701,360 cubic feet. This dam backs up the water into Cass Lake. (See Colonel Farquhar's report, 1875.)

VERMILLION RIVER DAM.

This is situated on the Mississippi River, just below the mouth of Vermillion River (see map). It is calculated for a rise of 10 feet.

	Cubic feet.
Capacity at 10 feet	5,770,828,800
Supply by first method	8,449,942,760
Supply by second method	8,400,321,448
Total surplus by first method	2,916,080,360
Total surplus by second method	2,881,933,388

This surplus is counted in total surplus for Pokegama Dam.

POKEGAMA FALLS DAM.

This is the distributing reservoir, and is situated at the head of the falls. It is calculated for a rise of 7 feet.

	Cubic feet.
Capacity at 7 feet rise	3,751,791,436
Supply by first method	3,493,156,520
Supply by second method	5,117,636,126
Total surplus by first method	2,657,445,444
Total surplus by second method	4,247,778,348

This last surplus gives for 90 days the quantity last given, or per day, 47,197,537 cubic feet; or per second, 547 cubic feet.

Summary of supply of water to reservoir above Pokegama Falls.

Name of reservoir.	By first method.	By second method.
	Cubic feet.	*Cubic feet.*
Leech Lake	19,534,394,880	15,460,977,021
Mud Lake	3,122,380,800	3,137,855,040
Lake Winnebigoshish	36,922,152,960	37,773,739,000
Vermillion	8,449,942,760	8,400,321,448
Pokegama Falls	3,493,156,520	5,117,636,126
Total supply	71,522,027,920	69,890,528,635

The second method of calculation has been adopted, so that we may say that, in round numbers, we have a supply of 70,000,000,000 cubic feet on hand on the 1st of July.

Now, it is believed that the lower river, above Aitken, can take care of itself before

July 1, as its watershed is upward of 2,500 square miles and its affluents numerous; but let us suppose the worst case possible, viz, that after May 1, the earliest date that navigation ever begins, we have to supply the lower river as far as Aitken. We know from careful observations, in 1874, that 2,500 cubic feet per second discharged at Pokegama Falls gives excellent navigation as far as Aitken, and, it is to be presumed, for a much greater distance down, as the river is deep, except in a few instances, where obstructions, such as small rapids, &c., exist, to below the mouth of the Crow Wing River. Now, from May 1 to November 1, six months, or 180 days, will require, at 2,500 feet per second, in round numbers, about 37,500,000,000 cubic feet, leaving us with 32,500,000,000 cubic feet in store to supply the lower river in addition, for a period of 120 days, from July 1 to November 1, which gives us 3,135 feet per second.

But we have, further, a constant supply from Pine and Gull Lake Rivers, as shown by the surveys of 1874 (see Colonel Farquhar's report, 1875), of 1,062 feet per second, which being added gives us a total supply of 4,197 cubic feet per second, and this while 2,500 cubic feet per second was being added to all the resources of the river below Pokegama Falls. Mille Lacs might possibly furnish a small further supply, but I do not think it safe to count it. Further, in the case under consideration, were the dams opened on May 1, in order to supply the 2,500 cubic feet, there would be no surplus, as it would not have collected. We are, therefore, entitled to add the amount of that surplus, viz, 547 cubic feet, which gives us a total of 4,744 cubic feet per second.

Now, from accurate gauging, in 1875, of the Mississippi River above the Falls of Saint Anthony, and the Minnesota River at its mouth, we know that we can set the low-water discharge at Saint Paul at 5,800 cubic feet per second. Now we can add to this 4,744 cubic feet from the reservoirs, making a total amount passing Saint Paul at extreme low water of 10,544 cubic feet per second.

It must be borne in mind that the case supposed on which these estimates are based can never occur, as the river below the falls and above Aitken must always have some water running. I think it would be perfectly safe to add one-half of the amount allowed (2,500 cubic feet per second) to the foregoing estimate. We would then have—

	Cubic feet.
Former amount	4,744
Added	1,250
Total amount furnished at Saint Paul	5,994
Low-water discharge	5,800
Total amount passing Saint Paul at low water, cubic feet per second	11,794

There is still further reason, amounting almost to a certainty, for the belief that the Mississippi River below Pokegama Falls, can be supplied from its own watershed with ample water for all purposes of navigation prior to July 1, and it is absolutely certain that before that time the river below Aitken is entirely independent of the discharge at Pokegama.

The character of the two districts is entirely different. Above the falls the whole country is, in a certain sense, a reservoir. It receives and retains vast quantities of water, which drain off slowly. Large lakes, with very slight differences of level, and immense marshes bordering them, retain the waters from the higher portions of the basin and part with them slowly. There are no freshets, no sudden rise or fall in the surface of the lakes or streams. All changes are so gradual as to be scarcely perceptible. The extreme range of Leech Lake is only 1.7 feet, and this is only the gradual change from a very wet season to a very dry one, and is due largely to evaporation. A reference to the general map on file in Washington will show the character of the region, and it will be seen from the sheets of gauge-readings hereto attached that at and above Grand Rapids the gauge curve is practically an unbroken line. Below Grand Rapids the whole country is different. The river becomes a true river, with defined banks, and is fed by numerous tributaries, while above there are only a few small streams that lose themselves in swamps before they join the river. Three miles below Grand Rapids is Prairie River, a rapid stream, which at times of high-water discharges large volumes and is subject to freshets. It produces such an effect on the river at Grand Rapids, that when the gauge above the falls showed a steady decline the gauge at the foot of Grand Rapids has been known to mark a rise of a foot. The Split Hand, Wild Swan, Sandy Lake, Rice, Mud, and Willow Rivers are important tributaries. This last drains a very large area as will be seen from the maps. A reference to the gauge readings and a comparison of the curves above and below will show plainly the wide difference in the character of the two portions of the river. The upper are almost unvarying; the lower subject to sudden changes. As to the date set, July 1, it is not too much to say that low-water has never occurred at or before that time. It will be seen, by a reference to Table A, that May and June have the largest rainfall in the year, and that June is notably the month with largest mean. It is, besides, universally known as the high-water month. A decline to low-water by the 1st of July is almost impossible. It has at least never recurred. We have a fair right, therefore, to conclude that July 1 will never find the upper river without sufficient water for purposes of navigation. There is only one place at which any continuous record of gauge readings has been kept in this district, and that is at Saint Paul, where the Signal Service records extend over a period of seven years, from 1872 to 1878, and this includes some years of very low water, and the highest does not reach midway the range between high and low water. The mean reading for July 1 is 6 feet 2 inches above low-water, while the gauge at Aitken on July 15 was 7½ feet above low-water, 1874. We have before said that the area of the watershed below Pokegama and above Aitken is 2,500 square miles. Now, using the second method of computation before described, which comparisons given would seem to establish as just, this will furnish at Aitken, continuously, up to July 1, 4,362 cubic feet per second, while in 1874 a discharge (measured) at the same place of 3,088 feet per second gave much more than the necessary depth of water required for navigation. It would seem, then, that it is abundantly established that we can shut off the entire river above Pokegama Falls up to July 1 without interfering with navigation below. But in that case we should have a surplus of 547 cubic feet per second to be added to the volume below, which would enable us to add 1,250 cubic feet per second to the last amount before given as passing Saint Paul, viz, 11,794 cubic feet per second, making the total amount 13,044 cubic feet per second, or, deducting the low-water flow at Saint Paul, 5,800 cubic feet per second, we can supply from the reservoirs above Pokegama Falls 7,244 cubic feet per second for a period of 120 days after July 1.

COST OF DAMS.

There has been no time as yet to make detailed drawings and plans for the different dams. Careful estimates have been made from the different cross-sections, and I have been able to find nothing to lead me to alter the estimates made by me in 1874, except in the case of the Leech Lake dam.

The cost of this our examinations this year enable me to reduce to $55,000. The estimate as corrected would stand—

Leech Lake	$55,000 00
Mud Lake	31,737 20
Lake Winnebigoshish	59,969 80
Vermillion River	56,245 20
Pokegama Falls (masonry and movable dam)	75,334 00
Pine River	32,386 20
Gull Lake River	25,786 20
Total cost of system of dams	336,458 60

Should only sufficient money be appropriated for the building of one dam, it would be advisable to erect that at Lake Winnebigoshish first. It is the principal reservoir, containing more than half of the water to be withheld above Pokegama Falls. It is in a very favorable position as far as timber, convenience for sheltering men, and delivering supplies; and for the same amount of money would better than any other illustrate the working of the proposed system.

DAMAGE RESULTING TO PROPERTY FROM OVERFLOW.

The land overflowed is almost entirely on the Indian reservation above the Vermillion Dam. There is no land under cultivation, but some hay-meadows would be submerged, and the wild rice, on which the Chippewas largely subsist, would for a few seasons be drowned out. This, however, would probably find its way to the surface in time and be as luxuriant as ever. Below Vermillion River are extensive meadows along the river owned by lumbermen, from which they derive annually their hay for their stock during their winter logging operations. This, after the erection of the dam at Pokegama Falls, would be cut off and the meadows ruined. Hay, however, could be obtained elsewhere, though with less convenience. Of course provision would have to be made for the passage of logs through the several dams. This is all the damage that could be sustained, the country being entirely given up to Indians and lumbermen.

Before leaving this part of my report, I would express my conviction of the entire feasibility of the proposed system, and also that efficient aid would be given to the navigation of the Mississippi River at least as far as the head of Lake Pepin. I would also acknowledge the intelligence and zeal with which Assistants McCalman and Davenport discharged the duties assigned them.

SAINT CROIX RIVER.

We come now to the consideration of the Saint Croix River, and the practicability of constructing reservoirs on its headwaters, with a view to beneficially aiding the navigation of the Mississippi below their junction. The party engaged in making the surveys necessary to determine this was under the charge of Mr. H. S. Treherne, assistant engineer. Their duty was to select the most suitable dam-sites, to make a thorough instrumental examination of the country each side of the proposed dam, to run a line of levels sufficiently far up-stream to determine height of the dam, if not limited by natural features at the site, to make a detailed survey of the latter, to establish the flowage line and contours of the whole reservoir, and to gauge the streams in the vicinity of the dams and at other points. He was also instructed to obtain as much information as possible as to the location of lumbermen's dams and their operations, the general features of the country, and the character of streams which the limited time would not admit of his surveying. It was not possible to run a connected line of levels, but a datum was assumed for each locality surveyed and numerous benches left in prominent and accessible places for use another season, when the whole system could be connected and the levels carried down to the Saint Croix River and connected with some point on the Saint Paul and Duluth Railroad, thus reducing all elevations to the sea-level. Before enumerating the different localities examined, it would be well to give a description of the country through which the Saint Croix River and its tributaries flow, both on the Wisconsin and Minnesota sides. This last was not examined this year, but is well known to me.

DESCRIPTION OF THE COUNTRY.

The Saint Croix River rises in Upper Lake Saint Croix, a sheet of water about 4½ miles long and a half mile wide, lying at the foot of the ridge that divides the waters flowing into Lake Superior from those reaching the Gulf. This ridge is 1½ miles wide and its lowest summit elevation is 14 feet above Lake Saint Croix. It is full of springs, the two principal ones being 25 feet apart and their waters running in opposite directions. The banks and bed of the lake are also filled with springs. The tracing of progress map No. 3 will show its course and direction. Its main tributaries are on the Wisconsin side—the Eau Claire, Totogatic, Namekegon, Yellow, and Clam Rivers; and, on the Minnesota side, the Kettle and Snake Rivers. The country through which the two latter pass is very different from the Wisconsin side. It is a heavily-wooded district, white and Norway pine alternating with hard-wood timber. The soil is of a much better character than on the other side. Extensive lumbering operations are carried on on both these streams, and on Snake River large dams are erected for milling and log-driving purposes. On the Wisconsin side numerous dams are built on the river proper and its tributaries for driving purposes, a full list and description of which is given in the report of Assistant Treherne, on file in this office. There also is on file a full list and description of these dams, with their discharge and the effect on the reservoirs on opening the gates, given by Mr. A. W. Chase, superintendent of dams on the Saint Croix, to whom I am under great obligations for valuable information furnished the party before taking and while in the field. These dams are all marked on the progress map, and lettered *a b c* in red. The three located dam-sites and reservoirs are marked A, B, and C on the progress map.

Of the valley of the Saint Croix, Assistant Treherne says: "In the bed and on the banks of Lake Saint Croix there are numberless springs. The banks on the east and west are 20 to 25 feet high; on the north is a large hay meadow, north of which is a very large cedar swamp, extending over the dividing ridge between the Saint Croix River and the Bois Brule River, and for some miles down the latter stream. The Saint Croix River above its junction with Moose River is not very rapid. From Upper Saint Croix Lake to half a mile north of the junction of the Saint Croix and Eau Claire Rivers the former is 6 miles long and falls 2.109 feet, and is one continuous rice-field, from which the Indians in the vicinity procure their staple food.

From half a mile above the mouth of Eau Claire River to the Big Dam the river has but very little current, falling 6.657 feet in 9 miles.

Between the Big Dam and the mouth of Moose River, a distance of 18 miles, the river falls 18.019 feet. The river is very tortuous throughout its whole length. Below the Big Dam, the river bed is rock, whereas above, it is pure sand or sand and mud. The valley banks are composed of gravel and drift clays covered with sand. On the ridges blackjack, pine, and black scrub-oak grow in abundance, with a Norway pine here and there. In the lower lands tamarack, cedar, birch, poplar, spruce, and balsam, with scattering small soft maples, grow thickly. Willows and alders grow in vast profusion. The whole Saint Croix River region explored from section 3, township 43 north, range 13 west, on both sides of the stream to the head of Upper Lake Saint Croix, in township 45 north, ranges 11 and 12 west, is, except in the valley of the river, deeply covered with sand, in many places loose. Through this valley and the valley of the Bois Brulé River, it is evident that there was once a very large and powerful stream flowing, presumably from Lake Superior, when the elevation of that lake was higher by 400 feet than it is at present. This stream has cleaned out the sand from the valleys down to the drift clays and large gravel of the glacial period, which generally stretch in a northeasterly direction. In places these glacial deposits have been swept away, leaving bare the substratum of sandstone rock. The sand forming the general surface of the country does not arrange itself into dunes from the action of the winds, but must have been greatly disturbed since its deposit. The disturbing elements I should judge were of volcanic origin, namely, earthquakes and eruptions of a minor nature, since the sand formed itself into long irregular ridges running north 45° east to north 65° east, and into deep circular or nearly circular hollows. Nearly all of these depressions are partially filled with water, forming lakes or wet marshes, without any outlet, and in many cases without inlet. Nearly all of these lakes contain fish. As evidenced by the paucity of the streams except where the sands have been washed away, for the sand is too loose generally speaking to allow of surface drainage, the drainage is subterranean, the rainfall finding its way to the river along the surface of the underlying clay or rock. The rock is Potsdam sandstone, and is copper-bearing, since that metal has been mined near the crossing of the proposed dam. The line of upheaval of this rock is north 30° east, with a dip to the southeast of 17° from the horizon. It is of a very firm nature, and I should judge would prove an excellent building stone. When I found any of this stone exposed to the action of the air or water, I examined it closely, and found the action of the elements upon it was very slight indeed; in fact it was hardly perceptible.

DAM SITES AND RESERVOIRS SURVEYED.

There were three in number: one 1 mile below what is known as the Big Dam on the Upper Saint Croix River; one on the Totogatic River; and one on the Yellow River below the outlet of Yellow Lake. Maps and tracings of all of these have been made, showing contours of country, flowage lines, cross-sections at dam sites, and area of watershed and capacity. A reference to these and to Assistant Treherne's report will render any further description unnecessary here. As in the case of the Mississippi River, there is annexed a tabular statement of the area of basin, capacity, and supply of each reservoir, and the method of computing the same.

CAPACITY AND SUPPLY OF RESERVOIRS.

Upper Saint Croix Lake reservoir.

This has a surface area of 16½ square miles, or 459,792,500 square feet. The height of the dam will be 25 feet, and the surface of Upper Lake Saint Croix will be raised 12 feet. The total capacity of the reservoir is 4,698,269,800 cubic feet.

The supply is derived from an area of 290 square miles, or 8,084,736,000 square feet. The rainfall for this river is the same as in Minnesota—25 inches.

	Cubic feet.
One-third of which gives	5,659,315,200
Capacity before given as	4,698,269,800
Surplus	961,045,400

which can undoubtedly be retained by dams on the Eau Claire River. The capacity above given will furnish, for a period of 90 days, a supply of 604 cubic feet per second, and if the surplus were retained, 124 cubic feet per second could be added.

Totogatic reservoir.

This has a watershed of 330 square miles extent, or, in square feet, 9,199,872,000.

	Cubic feet.
This, by one-third rainfall, gives	6,439,910,400
The capacity of the reservoir is only	2,881,095,000
Leaving a surplus of	3,558,815,400

which I have no doubt further examination will enable us to retain.

The capacity furnishes us for 90 days, per second	370
The surplus would furnish for 90 days, per second	457

Yellow Lake reservoir.

The watershed is 321½ square miles, or 8,932,905,600 square feet

	Cubic feet.
Its supply (one-third rainfall) is	6,274,033,920
Its capacity is	3,402,712,000
Leaving a surplus of	2,871,321,920

The capacity furnishes per second for 90 days	438
The surplus would furnish per second for 90 days	369

RECAPITULATION.

Total supply from the reservoirs examined on the Saint Croix.

	Supply.	Surplus.
	Cubic feet.	*Cubic feet.*
From Yellow Lake reservoir we can draw for a period of 90 days, per second	438	....
But there is a surplus which, if it could be held back, would give in addition, for 90 days, per second	....	369
From Totogatic reservoir for same period, per second	370	....
Surplus, per second	....	457
Upper Saint Croix Lake reservoir for same period, per second	640	....
Surplus which, could it be retained for same period, would give, per second	....	124
Total	1,412	950

That is, from the few reservoirs already examined, we could deliver to the lower river, for a period of 90 days, 1,412 cubic feet per second, and could the surplus waters be retained for a like period, we could, from these three sources alone, furnish a total of 2,362 cubic feet per second.

There still remains to be examined the remainder of the three above-named rivers, the whole of the Namekagon River, itself more extensive than the Saint Croix above their junction, the Kettle and Snake Rivers. Energetic work by one party for the entire season will not more than complete this examination. We have not yet gone far enough in our surveys to hazard an opinion as to what, if any, aid could be afforded to navigation on the Mississippi River below the mouth of the Saint Croix. It would be well worth the while to make a survey of the mouth of the Saint Croix River at Prescott, to ascertain the practicability of constructing a lock and dam at that point. Were this practicable, and did it not conflict too strongly with existing interests, it would solve the whole problem. All the surplus waters of the Saint Croix could be retained at that point, and the whole system of dams on the headwaters done away with. The logging interests would not be interfered with, as they could use their own dams as they pleased, and the water, after having been used by them, would be retained below. One thing, however, is certain, that should the plan of reservoirs at the sources prove feasible, the lumbering interests will have to be made subservient to those of navigation; otherwise any system of reservoirs would prove useless. Assistants H. S. Treherne and George R. Stuntz discharged the duties assigned them with fidelity and obtained a large amount of valuable information. No estimate of the cost of dams is submitted, both on account of the incipient stage of the work and the lack of time to make the necessary plans.

GAUGING OF THE STREAMS.

The party under Mr. Treherne gauged the rivers at the dam sites. Another party, under Mr. W. H. Fuller, assistant engineer, gauged the Saint Croix River at various places, from the mouth of the Namekagon to Taylor's Falls. Gauge-readings were also recorded at Stillwater, Taylor's Falls, and points above. These last are plotted, and the plats appended. A tabular statement of the discharges at the points gauged, the areas of cross-sections, height above low-water, &c., is hereto annexed, and marked D.

DAMAGE TO PROPERTY.

The damage caused by overflow is very slight, consisting only of the drowning out of wild rice-fields on the Upper Saint Croix and the submergence of a few meadows and fields near the entrance of the Eau Claire River at Amick (Antoine Garden's). It is hardly worth mentioning.

HEADWATERS OF THE CHIPPEWA RIVER.

The Chippewa River takes its rise from numerous small streams and lakes that lie along the south side of the ridge that separates it from the waters flowing into Lake Superior. Two branches uniting at "Flambeau Farm" form the main stream. The east and principal fork is known as the Flambeau River, and the west fork as the Chippewa River, a title more properly belonging to the Flambeau, as the discharge of the latter considerably exceeds that of the former. The total watershed above the junction of these two branches is, on the Flambeau, 1,960 square miles, and on the Chippewa 1,801 square miles, making together a sum of 3,761 square miles. Not all of this area, however, will avail toward supplying reservoirs. Below the mouth of Turtle River, on the North Fork of the Flambeau River, and Little Chief Lake, on the Chippewa River (see map showing watershed in Wisconsin), the streams flow through narrow valleys, and are full of rapids and falls. Below the points named none but the most temporary reservoirs for the storage of water can be secured. Dams have been erected for logging purposes, but when the gates are opened they empty themselves in a day or two. There is no holding ground that could give a supply for any length of time. We are, then, limited to the watershed above the points named as the area from which we must derive our supply of water for the river below.

	Square miles.
The total area on the Flambeau River	1,960
The total area on the West Fork	1,801
Total watershed above Flambeau Farm	3,761

But of this we only have an area to draw from—

	Square miles.
On Flambeau River	712
On West Fork	700
Total area to draw from	1,412

which will give us, in case we can utilize all the water available from it (a very improbable supposition), 3,900 cubic feet per second for a period of ninety days. No instrumental examination was made of the West Fork this year, the amount of funds allotted not allowing another party to be put in the field; but sufficient information was gained to warrant the assumption that a fair portion of the waters due to its 700 square miles area can be made available. The surveys were therefore confined to the Flambeau River, the north fork of this stream being the theater of operations. Mr. John H. Dager, assistant engineer, was in charge of these surveys, assisted by Messrs. Parker, Foss, and Redfield. All of these discharged their duty with industry and ability. These duties were precisely similar to those of the Saint Croix party.

DESCRIPTION OF THE COUNTRY.

The North Fork of the Flambeau River above the crossing of the Wisconsin Central Railroad to a point half a mile above the mouth of the Turtle River (see progress map, No. 2) is a succession of still reaches and sharp "pitches" or rapids, there being in that distance (21 miles) a fall of 85 feet. The rapids are 29 in number, some of which are quite precipitous and dangerous to pass. The only mode of transportation is by log canoes, which are poled by skillful boatmen. On the Turtle River, above the rapids, the character of the stream changes, up to what is known as "30-foot Falls," where a dam-site was selected and a survey made. Assistant Dager says, in his report, on file: "The valley is of considerable width, being from one-fourth to one-half mile wide. The stream is quite crooked, working its way across the valley from ridge to ridge. On one or the other side are found hay-meadows, while on the higher land small areas of pine are seen." On the Flambeau, below Turtle River, the timber is of various kinds; birch, ash, soft maple, and poplar on the lower lands and on some of the ridges. On most of the latter, however, white or Norway pine is found. Of the river above the rapids, just above Turtle River, and the Manadonish above its junction to Rest Lake (see map), where another excellent dam-site was found and a survey made, Assistant Dager says: "The river has few rapids, but is one of the crookedest imaginable; the bottom and banks are fine sand and loam, though below the junction of the Manadonish a cluster of bowlders occurs about every mile. Considerable pine, mostly second growth, is found on the high lands, with more poplar and soft wood than is generally seen, up to the junction; above this there is no timber of value; the country is mostly covered with brush. The land is valueless, full of swamps and sink-holes. The valley of the river is from ½ to 1 mile wide, with large grass-meadows on either side; these I learn are considered quite valuable, and have all been taken up by lumberman. No indication of rock in place is seen within the limits of this survey."

The fall of the river from the dam-site at Rest Lake to the junction of the Manadonish and Flambeau Rivers is 18.7 feet. Thence to the crossing of the Wisconsin Central Railroad below Muskelonge Falls the fall is 107 feet, making a total fall in a distance of about 75 miles by river of 125.7 feet, 85 feet of which is below the head of the rapids just above Turtle River. A survey was also made of a dam-site and reservoir on Butternut Creek, which enters into the Flambeau below the railroad crossing.

DESCRIPTION OF THE WORK DONE.

The work was, as before said, similar to that on the Saint Croix. Flowage-lines were run out and accurate cross-sections made. The stream was carefully gauged at each dam-site, although in one, Butternut Lake, the stream was so very low that the results were not satisfactory. Observations to show evaporation and temperature were made daily, and tables of discharge of the streams are hereto appended, being among the general discharge and velocity tables which form part of this report. A general map of this district, showing the different watersheds and the supply to and the capacity of the reservoirs has been made. It is marked Progress Map No. 2. Detailed maps of the dam-sites and reservoirs have also been made, and tracings of all these accompany this report. A table showing the manner in which the results hereafter given were obtained is also appended. A line of levels was run from the most elevated lake in the system at the head of the Manadonish River to the foot of Muskelonge Falls at the crossing of the Wisconsin Central Railroad and there connected with their system, thus enabling us to reduce the elevations to the sea-level. The elevations, so reduced, of the different lakes and the water surface at the different points on the river are marked on progress map No. 2 in blue figures. The elevations in red figures are from an assumed local datum.

DAM SITES AND RESERVOIRS.

The first of these is at Butternut Lake and is not of great value. The area of the basin tributary to this reservoir is 55 square miles, or 1,533,312,000 square feet. The average rainfall is 30 inches, one-third of which (10 inches, or 0.83 feet), is taken as available. This will give a supply of 1,272,648,960 cubic feet. The height to which the water can be raised above the surface of Butternut Lake (see detail map) is 10 feet.

The capacity of the reservoir is 585,446,400 cubic feet, which taken from the supply leaves a surplus of 687,202,560 cubic feet. The reservoir can furnish for a period of 90 days, per second, 75 cubic feet, while, could we retain it, the surplus would add, per second, 89 cubic feet.

PARK LAKE.

The second reservoir is just above the "30-foot Falls" on Turtle River (see detail map). Its supply is as follows:

	Cubic feet.
Area of watershed, 174 square miles, or	4, 850, 841, 600
This will give a supply of	4, 026, 198, 428
The capacity is, with 15 feet rise at dam	620, 782, 720
Which leaves a surplus of	3, 405, 415, 708

The capacity will give for a period of 90 days 82 cubic feet per second. It is possible that further examination may enable us to retain this surplus. In that case we could add, per second, 518 cubic feet.

REST LAKE RESERVOIR.

This is the most important of the three surveyed. The water can be raised 25 feet and the dam-site is an excellent one. The detail map will show its characteristics. Its capacity will exceed its supply, the former being 5,645,376,000 cubic feet, while the latter is 4,897,100,264 cubic feet. We can draw from this reservoir for a period of 90 days, per second, 730 cubic feet. The following is a recapitulation of the water that can be furnished from the three reservoirs surveyed:

SUMMARY.

Total supply furnished by the reservoirs examined this season on the headwaters of the Flambeau River, or, more properly, the East Fork of the Chippewa River.

	Manadonish River.	
	Supply.	Surplus.
RESERVOIR AT REST LAKE.	*Cub. feet.*	*Cub. feet.*
From this we can draw for a period of 90 days, per second	730	
From reservoir at Turtle River we can draw for a period of 90 days, per second	82	
While, could the surplus be elsewhere retained, we could add to the above, per second		436
From reservoir at Butternut Lake, for a like period, we can furnish	75	
While, could we retain the surplus, we could add, per second		89
Total	887	525

RESULTS.

That is, as far as we have gone, which is only a very little way. We can supply to the Chippewa River from the North Fork of the Flambeau River alone 887 feet per second, and could we retain the surplus, we could furnish 1,412 cubic feet per second. I have not included the South Fork of the Fambeau River, nor that portion of the North Fork which lies between Rest Lake and the junction of the Manadonish and the Flambeau Rivers. These, I have no doubt, would increase the supply considerably. I have said before that we were limited to the watersheds mentioned. The Eau Claier River and Red Cedar or Menominee River, it is possible, might furnish from reservoirs a useful addition to our supply. These two streams, however, are controlled by private parties, who have numerous dams upon them, for the purpose of furnishing water and logs to their mills. On the Menominee alone there are upwards of 25 dams, and on the Eau Claire River there are 4. These dams occupy all available points on the river, and there is nothing left for the United States to do, unless they were to take the control of the dams away from the owners and manage them. They are not, therefore, considered. I have not touched upon the Lower Chippewa. Mr. Charles Wanzer, assistant engineer, made an examination of the river from "Flambeau Farm" to the mouth, and has made a full report thereon. He gauged the river and its tributaries at various points very accurately, and has contributed greatly to a knowledge of the Chippewa River.

The tabulated discharges, areas of cross-sections, velocities, &c., are contained in the table of discharges annexed to this report, marked D. The dams on the Menominee and Eau Claire, as managed, do no damage to navigation. Very different is the effect of the Little Falls dam, used for driving logs. Mr. Wanzer fully describes this in his report, and the gauge curves on the sheets hereto annexed strikingly illustrate the sudden fluctuations caused by the opening and closing of the gates.

HEADWATERS OF THE WISCONSIN RIVER.

It was expected that the party on the Chippewa River, after finishing the surveys before described, would cross over from the Flambeau, and, coming down the Tomahawk River, examine the dam-sites which were reported to exist on that stream. This, however, they were unable to do, and Assistant Wanzer, with a small party, was sent to make the desired survey. He left Saint Paul on November 19, and returned, having completed his examinations on the Tomahawk River on December 13. Great credit is due to him for the intelligence and activity with which he performed his work. Two dam-sites and reservoirs were surveyed, and much valuable information obtained. The examination of that region, however, is only begun, and an entire season's work will be necessary to complete it.

DESCRIPTION OF THE COUNTRY.

The headwaters of the Wisconsin River are in close proximity to those of the Flambeau, the dividing ridge being in some places less than a mile in width. The character of the country is the same. The Wisconsin River rises in Lac Vieux Deserts, which lies on the boundary line between Wisconsin and Michigan. A full description of the river from its source will be found in the report of Maj. D. C. Houston, dated January 21, 1878. Of the Tomahawk, Assistant Wanzer says:

"The river from its mouth to the junction of the Summo River is about 300 feet in width, after which it narrows down to an average of 130 feet, and so continues to a distance of 10 miles. The current is generally swift, and for the first 2 miles the bottom is rocky, the succeeding 8 miles being mud and sand. At this point Prairie Rapids are reached, which have a fall of 7.5 feet in a distance of 450 feet, the stream here being full of large bowlders. These rapids are the second on the river, and will be "flowed out" by the proposed dam, which is located 6½ miles above the mouth. The first rapids are situated below the proposed dam, beginning 1,500 feet from the mouth of the river and having a fall of 19 feet in the space of a mile. The Little and Big Rice Rivers, which join the Tomahawk River 7 miles above the mouth, are very sluggish and tortuous streams. The banks are entirely of sand, covered with Norway pine, and the bottom lands are hay-marshes. These two streams furnish the best holding ground for a reservoir that is to be found on the river in that vicinity. At the proposed upper dam the river is only 40 feet wide, and has a swift current, the fall from Tomahawk Lake to the dam-site being 38.8 feet. From this point the banks are high and contracted, affording little holding ground. The bottom of the river is rocky and slight rapids are frequent. Squirrel Creek joins the main river (see progress map No. 1) immediately above the located dam-site and is a comparatively sluggish stream, the banks and marshes being similar to those of the Little and Big Rice Rivers, and the lake itself affording a fair but insufficient holding capacity, which I believe a more detailed survey will considerably increase. There is no doubt that supplementary sites may be selected above the present proposed dam, which would probably give one or more of the lakes near the head of the Tomahawk as a reservoir for flooding purposes.

"The country adjoining the river from the mouth of Tomahawk Lake, which is its source, is sandy and covered with a small growth of Norway pine, and is dotted with small lakes. Very little pine fit for logging purposes remains on this stream; the ravages of fire having destroyed nearly all that has not been cut."

DAM SITES AND RESERVOIRS.

Below the mouth of the Tomahawk River there would seem to be no suitable places for reservoirs, judging from the information obtained from the most reliable sources. Above these are two good dam sites commanding the whole watershed above the mouth of Pelican River, an area of 830 square miles. The supply from this basin, if it could all be utilized, which is not probable, would give 2,470 cubic feet per second, for a period of 90 days. Two dams have already been erected, one just above the mouth of Pelican River and another 30 miles above, below the mouth of Eagle River, at a point which is known as Otter Rapids. The first has a watershed of 444 square miles, the last one of 386. The data that I have been able to obtain as to the operations of these dams are as follows: The Upper or Otter dam has raised the water above it to a height of 4 feet above ordinary level. I am informed that it can easily be raised 12 feet.

The lower or Pelican dam allows of a rise of 9 feet, and can be also raised so as to admit of 12 feet. This last dam, when the water is raised 9 feet, backs up the water 22 miles, or within 8 miles of the Otter dam. The upper reservoir, with 4-foot head when the gates are opened, requires from a week to ten days to empty itself. When it has discharged its contents into the Pelican dam below, the latter reservoir is raised to a height of 8 feet 10 inches, and when the gates of this are opened a rise of 4 feet at Jenny, 65 miles below, and a rise of 3 feet at Warsaw, another 65 miles further down, ensues. These are the facts given to me by the lumbermen. No examination has as yet been made. On the Tomahawk River, the main affluent of the Upper Wisconsin, the dams surveyed by Assistant Wanzer will enable us to supply water to the river below as follows:

Upper dam (see sheet No. 1, detail map):

Area of watershed 200 square miles	5,575,680,000 square feet.
	Cubic feet.
Which by one-third of rainfall of 30 inches gives	4,627,714,400
Capacity of reservoir	2,000,000,000
Surplus	2,627,714,400

The reservoir would furnish, for a period of 90 days, 257 cubic feet per second. Could the surplus be retained there could be added, per second, 338 cubic feet.

Lower dam (see detail map, sheet No. 2):

Area of watershed 38 square miles	10,593,792,000 square feet.
	Cubic feet.
Which by one-third rainfall gives	8,792,847,360
Capacity of reservoir at 14 feet rise	1,043,516,880
Surplus	7,749,330,480

Which probably cannot be retained. The reservoir will furnish, for a period of 90 days, per second, 134 cubic feet. To summarize the above results, we have—

	Cubic feet.
From upper dam for 90 days, per second	257
From lower dam for 90 days, per second	134
Total ascertained supply from Tomahawk	391

So little has yet been done on the Wisconsin River headwaters that it would be idle to express an opinion, but the limited area of the available watershed would seem to render it doubtful if much efficient aid could be given to the Mississippi River below the mouth of the Wisconsin. One thing, however, is certain, and that is that, from what experience we have had on the three above-named rivers, and with the information we have obtained, we are in a position to make the surveys, to be made the coming season, much more complete and thorough, and at a less proportionate cost. We have parties of men trained to the work that can be got together at short notice. A knowledge of the country has been acquired, and the mistakes, that are inevitable with a new party and untried assistants, to whom the country is new, can be avoided.

METEOROLOGICAL OBSERVATIONS.

Meteorological stations have been established at the three Indian agencies which are situated near the sources of the Mississippi River, one at Red Lake on the north of the watershed, one at White Earth on the west, and one at Leech Lake on the south. The observers at all of these stations keep a record of rainfall and snow and evaporation. At Leech Lake a record of temperature and readings of the water-gauge are also kept, while at White Earth, besides that of the temperature there is added a record of readings of the anemometer. These records, if kept for a sufficient length of time, will give us, what we most need, an accurate idea of the rainfall of that most important region, as well as the daily and monthly evaporation, temperature, &c.

With the opening of the rivers gauges should be established at suitable points on the Mississippi River from Pokegama Falls to Saint Paul, on the Chippewa River from its sources to its mouth, on the Saint Croix River from Upper Saint Croix Lake to Prescott, and on the Wisconsin from the Tomahawk to Portage. It is presumed that gauge-readings will be taken below Portage by those in charge of the Fox and Wisconsin river improvement.

Respectfully submitting the above,

I am, your obedient servant,

JAMES D. SKINNER,
Assistant Engineer.

To Maj. CHAS. J. ALLEN,
Corps of Engineers, U. S. A.

TABLE A.—*Annual and monthly means of rainfall in Minnesota, from data furnished by the War Department, up to* 1878.

Month.	Fort Snelling.	Fort Ripley	Fort Ridgely.	Saint Paul.	Grand mean.
January	0.97	0.85	1.51	0.88	1.07
February	0.76	0.92	1.36	0.97	1.00
March	1.31	1.55	1.61	1.78	1.56
April	2.13	1.62	1.60	2.20	1.89
May	3.40	3.08	2.88	3.75	3.28
June	3.80	4.33	2.59	5.82	4.13
July	3.01	4.14	2.67	2.68	3.07
August	3.24	3.11	4.02	3.96	3.58
September	3.42	3.28	3.22	3.09	3.25
October	1.39	1.60	1.65	2.08	1.68
November	1.49	1.73	1.18	1.17	1.39
December	0.94	0.91	1.12	0.72	0.92
From				1859 to 1866	
To	1836 to 1878	1849 to 1877	1855 to 1867	1871 to 1878	
Period	31 years.	19 years.	13 years.	7 years. 8 years.	
Mean	25.89	27.31	25.31	25.09 29.05	26.41

Annual and monthly means of rainfall in Dakota Territory, from data of War Department, to 1878.

Month.	Fort Abercrombie.	Fort Pembina.	Totals.	Grand mean.
January	0.52	0.18	0.70	0.35
February	0.55	0.34	0.89	0.44
March	1.01	0.70	1.71	0.85
April	1.54	1.17	2.71	1.35
May	2.16	2.65	4.81	2.40
June	3.20	3.91	7.15	3.51
July	2.23	2.81	5.04	2.52
August	2.63	2.64	5.27	2.63
September	1.66	1.24	2.90	1.45
October	0.96	1.24	2.20	1.10
November	0.64	0.52	1.01	0.50
December	0.70	0.77	1.51	0.75
From To	1860–1877	1871–1878		
Period	17 years.	8 years.		
Mean	18.44	16.91	35.25	17.67

It being evident that the rainfall decreases as the Red River Valley is approached, it would not be safe to count on more than 25 inches as the rainfall around the sources of the Mississippi River, which has been adopted.—J. D. S.

Rainfall, Dakota, up to 1868.

Location.	Extent.	Spring.	Summer.	Autumn.	Winter.	Total.
Fort Randall	1857–'67 $8\frac{10}{12}$	4.76	6.64	3.90	1.21	16.51
Fort Pierce	1855–'57 $1\frac{10}{12}$	4.28	3.32	3.76	2.15	13.51
Fort Abercrombie	1860–'67 $6\frac{11}{12}$	4.67	7.49	3.36	1.82	17.34

Rainfall, Wisconsin, up to 1867.

Location.	Extent.	Spring.	Summer.	Autumn.	Winter.	Total.
Fort Winnebago	1836–'45 9	5.58	11.46	7.63	2.82	27.49
Fort Crawford	1830–'45 $9\frac{3}{12}$	7.63	11.87	7.90	4.00	31.40
Milwaukee	1841–'66 $23\frac{4}{12}$	7.98	9.64	7.96	4.82	30.40
Superior	1856–'66 $7\frac{9}{12}$	6.14	8.68	7.64	3.18	25.64
Appleton	1856–'61 $4\frac{7}{12}$	7.46	10.24	7.43	5.93	31.06
Ashland	1856–'62 $4\frac{2}{12}$	13.50	13.95	13.93	5.07	46.45
Green Bay	1864–'68 $1\frac{9}{12}$	6.03	9.81	11.52	4.46	31.82

Rainfall, Minnesota, up to 1868.

Location.	Extent.	Spring.	Summer.	Autumn.	Winter.	Total.
Fort Snelling	1836–'67 $22\frac{4}{12}$	6.68	10.50	6.38	2.26	25.82
Fort Ripley	1850–'67 $16\frac{10}{12}$	5.86	10.90	6.31	2.04	25.11
Fort Ridgely	13	6.61	9.11	5.86	4.11	25.69
Lac qui Parle	1854–'62 $5\frac{2}{12}$	7.78	11.84	6.47	2.98	29.07
Saint Paul	1859–'66 5	5.63	11.11	5.46	2.89	25.09
Minneapolis	1865–'66 1	3.73	14.60	6.48	2.57	27.38
Beaver Bay	1858–'66 $6\frac{7}{12}$	7.89	8.56	6.27	4.48	27.20

TABLE B.—*Table of daily evaporation at the sources of the Mississippi River, autumn,* 1878.

Date.	Pan exposed.	Pan in shade.	Pan sunk in marsh.	Remarks.
August 26	0.08	0.00		
August 27				Rain.
August 28	0.12	0.07		
August 29	0.28	0.08		
August 30	0.30	0.15		
August 31	0.18	0.05		
September 1	0.17	0.06		Rain.
September 2	0.12	0.02		
September 3	0.21	0.03		
September 4	0.20	0.08		
September 5	0.02	0.01		Rain.
September 6	0.05	0.01	0.03	
September 7	0.17	0.08	0.08	
September 8	0.02	0.01	0.01	Rain.
September 9	0.00	0.00		Rain.
September 10	0.15	0.05	0.07	Rain.
September 11	0.08	0.06	0.07	
September 12	0.17	0.03	0.08	
September 13	0.15	0.04	0.08	
September 14	0.18	0.08	0.13	
September 15	0.14	0.05	0.11	
September 16		0.05	0.06	
September 17	0.17	0.13	0.09	
September 18	0.02	0.02	0.02	
September 19				
September 20	0.07	0.04	0.06	
September 21	0.13	0.08		
September 22	0.17	0.13	0.08	
September 23	0.13	0.10	0.04	
September 24	0.02	0.02	0.00	
September 27	0.12	0.07	0.10	
September 28	0.03	0.03	0.02	
September 29				Rain.
September 30	0.03	0.02	0.02	Rain,
October 1	0.07	0.03	0.03	Rain.
October 2	0.03	0.02	0.02	Rain.
October 3				Rain.
October 4	0.15	0.12	0.05	Rain.
October 5	0.10	0.09	0.06	
October 6	0.09	0.09	0.04	
October 7	0.07	0.07	0.04	
October 8	0.01	0.01	0.00	Rain.
October 9				
October 10	0.05	0.05	0.05	Rain.
October 11	0.15	0.12	0.05	
October 12	0.10	0.06	0.10	
October 13	0.10	0.10	0.08	
October 14	0.08	0.05	0.03	
October 15	0.02	0.01	0.04	
October 16				Rain.
October 17				Rain.
October 18				
October 19				
October 20	0.12	0.10	0.03	
October 21	0.03	0.03	0.02	
October 22				
October 23	0.08	0.08	0.02	
October 24	0.04	0.04	0.00	

	No. of days observed.	Evaporation.	Daily mean.
		Inches.	
Pan exposed	49½	4.97	0.1040
Pan in shade	50½	2.72	0.0538
Pan in marsh	39	1.81	0.0460
Days of no evaporation			Rain, 6.
Days of partial evaporation			Rain, 9.

TABLE C.

CAPACITY OF LEECH LAKE RESERVOIR WHEN RAISED 4 FEET ABOVE HIGH-WATER OF 1874.

	Cubic feet.
175.5 square miles, 4 feet rise	=19,570,636,800
43.5 square miles, 2½ feet rise	= 2,996,928,000
	22,567,564,800

Annual supply.

From rainfalls of 25 inches, taking 0.7 foot as the available supply:

Area of watershed, 1,001 square miles	=27,906,278,400 square feet.
Which multiplied by 0.7 foot	=19,534,394,800 cubic feet.

	Square feet.
In computing, 175.5 square miles	=4,892,659,200
In computing, 43. square miles	=1,198,771,200

Supplg to Leech Lake.

Calculated from flow of water as gauged:

	Cubic feet,
Mean low-water flow, 1878, per day	25,056,000
Mean low-water flow, 1878, per second	290

	Cubic feet.
For December, January, February, and March, 120 days' flow	=3,006,720,000
Three-fourths melted snow and rain for same period	=7,534,695,168
One-half rainfall April, May, and June	9,488,134,656
Total when dam is shut from December 1 to July 1	20,029,549,824
Evaporation subtracted for 90 days, at 0.1 inch per day, =9 inches on 218.5 square miles	4,568,572,803
Total in reservoir July 1	15,460,977,021

MUD LAKE.

Capacity with 6 feet rise above high-water of 1874:

Surface overflowed 17.25 square miles	= 480,902,400 square feet.
Which multiplied by depth, 6 feet	=2,885,414,400 cubic feet.

Supply from rainfall, assuming 0.7 inch as available:

Area of watershed	4,460,544,000 square feet.

	Cubic feet.
Which multiplied by 0.7 inch	3,122,380,800
Capacity	2,885,414,400
Surplus	236,966,400

Supply from flow of streams

	Cubic feet.
Mean low-water as gauged, 1878, per second	=290
Mean low-water as gauged, 1878, per day	25,056,000

	Cubic feet.
For December, January, February, and March, 120 days	3,006,720,000

Now this is all held back in Leech Lake, and we have only the low-water discharge of Mud and Bear Rivers, which at 75 feet per second for 4 months	=777,600,000
Three-fourths snow and rain	1,204,346,880
One-half rain, April, May, and June	1,516,584,960
	3,498,531,840
Less evaporation, 90 days, at 0.1 inch per day=9 inches	360,676,800
Total supply	3,137,855,040
Capacity	2,885,414,400
Surplus	252,440,640

LAKE WINNEBAGOSHISH.

Capacity, with rise of 14 feet above high-water, 1874.

Lake surface 74.11 square miles	= 2, 066, 050, 800	square feet,
Which multiplied by 14 inches depth	=28, 924, 711, 200	cubic feet.
Overflowed surface, 33 square miles	= 919, 987, 200	square feet,
Which multiplied by 8 inches depth	= 7, 359, 897, 600	cubic feet.
Overflowed on Mississippi River, between Winnebagoshish and Cass Lakes, 2.2 square miles	= 60, 984, 000	square feet,
Which multiplied by 10 inches depth	= 609, 840, 000	cubic feet.
Overflowed surface Cass Lake, 45.4 square miles	= 1, 265, 679, 360	square feet,
Which multiplied by 7 inches depth	= 8, 859, 755, 520	cubic feet.

RECAPITULATION.

Capacity for 14 feet rise in Winnebagoshish Lake:

	Cubic feet.
Lake Winnebagoshish proper	28, 924, 711, 200
Marsh overflowed	7, 359, 897, 660
Mississippi River	609, 840, 000
Cass Lake	8, 859, 755, 520
Total capacity	45, 754, 204, 380

Supply furnished reservoir at Lake Winnebagoshish.

1. From rainfall:

Average rainfall		25 inches.
Available		8.33 inches = 0.7 foot.
Area of basin 1,892 square miles	=52, 745, 932, 800	square feet,
Which multiplied by 0.7 inch	=36, 922, 152, 960	cubic feet.
Total supply from one-third rainfall	36, 922, 152, 960	cubic feet.
Total capacity at 14-inch rise	45, 754, 204, 380	cubic feet.

2. From flow of stream:

	Cubic feet.
Measured low-water flow = 540 feet per second, or per day	46, 656, 000
For December, January, February and March, 120 days	=5, 598, 720, 000
Three-fourths rainfall and melted snow, same period	14, 241, 401, 856
One-half rainfall, April, May, and June	17 933, 617, 152
Total supply	37, 773, 739, 008

VERMILLION RIVER DAM.

Capacity if water is raised 10 feet above high-water 1874:

Surface overflowed, 34.5 square miles	= 961, 804, 800	square feet.
Which, multiplied by 6 inches depth	= 5, 770, 828, 800	cubic feet.

Supply from rainfall:

Area tributary 433 square miles	=12, 071, 346, 800	square feet.
Which, multiplied by 0.7-inch	= 8, 449, 942, 760	cubic feet.

Surplus:

	Cubic feet.
Mud Lake	236, 966, 400
Rainfall	8, 449, 942, 760
Total entering reservoir	8, 686, 909, 160
Capacity	5, 770, 828, 800
Surplus entering reservoir below	2, 916, 080, 360

Supply calculated from flow of streams:

	Cubic feet.
Mean low-water flow below upper dams per second	100
Mean low-water flow below upper dams per day	8, 640, 000
For December, January, February, and March, 120 days	1, 036, 800, 000
Three-fourths melted snow for same period	3, 259, 263, 536
One-half rainfall April, May, and June	4, 104, 257, 912
Supply to July 1	8, 400, 321, 448

No evaporation allowed for here:

	Cubic feet.
Surplus Mud Lake	252, 440, 640
Total supply	8, 652, 762, 188
Capacity as above	5, 770, 828, 800
Surplus passing into Pokegama Falls	2, 881, 933, 388

POKEGAMA FALLS DAM.

Capacity if water is raised 7 feet above high-water 1874:

Area overflowed 23.61 square miles	= 658, 209, 024 square feet.
Multiplied by depth 5.7-feet	=3, 751, 791, 436 cubic feet.

Supply from rainfall:

Area of water-shed	4, 990, 223, 600 square feet.
Multiplied by rainfall 0.7-foot	3, 493, 156, 520 cubic feet.

Surplus:

	Cubic feet.
From above	2, 916, 080, 360
Supply	3, 493, 156, 520
Total	6, 409, 236, 880
Capacity	3, 751, 791, 436
Surplus pouring over dam	2, 657, 445, 444

POKEGAMA FALLS RESERVOIR.

	Cubic feet.
Mean low-water flow below Vermillion Dam, per second	200
Mean low-water flow below Vermillion Dam, per day	17, 280, 000
For December, January, February, and March, 120 days	2, 073, 600, 000
Three-fourths snow, &c., same months	1, 347, 360, 372
One-half rain, April, May, and June	1, 696, 676, 024
Supply	5, 117, 636, 396
Add surplus	2, 881, 933, 388
	7, 999, 569, 784
Deduct capacity	3, 751, 791, 436
Surplus passing over dam	4, 247, 778, 348
Or for 90 days, per day	47, 197, 537
Or for 90 days, per second	548

The above surplus discharge takes place without drawing upon the reservoirs in any way whatever.

FLAMBEAU REGION.

Reservoir at Butternut Lake.

Area of watershed, 55 square miles	1, 533, 312, 000 square feet.
Average rainfall, 30 inches.	
One-third rainfall, 10 inches = 0.83 foot.	
Amount of water	1, 272, 648, 960 cubic feet.
Surface area of reservoir, 2.1 square miles	58, 544, 640 square feet.
Multiplied by depth, 10 feet	=585, 446, 400 cubic feet.

	Cubic feet.
Supply	1, 272, 648, 960
Deduct capacity	585, 446, 400
Surplus	687, 202, 560
Supply for 90 days	1, 272, 648, 960
Supply for 1 day	14, 140, 544
Supply for 1 second	164
Capacity only	75
Discharge of streams as gauged, per second	22

Reservoir at Rest Lake.

Supply:

Area of watershed, 212 square miles	5, 910, 220, 800 square feet.
Average rainfall, 30 inches.	
One-third rainfall, 10 inches = 0.83 foot.	
Amount of water available	4, 905, 483, 264 cubic feet.
Capacity of reservoir, water-rise of dam, 25 feet.	

	Square feet.
Area of surface = 9.5 square miles =	264, 844, 800
To which must be added 10 square miles	278, 784, 000

	Cubic feet.
Now 264,844,800 by 7 inches depth	= 1, 853, 913, 600
And 278,784,000 by 10 inches depth	= 2, 787, 840, 000
	4, 641, 753, 600

Now also add for the 10-inch rise an area of 12 square miles = 334,540,800 square feet, which averages 3-inch depth = 1, 003, 622, 400 cubic feet.

	Cubic feet.
Total capacity	5, 645, 376, 000
Total supply	4, 905, 483, 264
Excess of capacity	739, 892, 736

Reservoir when filled can discharge for 90 days 730 cubic feet per second.

TURTLE RIVER RESERVOIR, PARK LAKE, ETC.

Area of watershed, 174 square miles	= 4, 850, 841, 600 square feet.
Average rainfall, 30 inches.	
One-third of rainfall 10 inches = 0.83 foot.	

	Cubic feet.
Available amount of water	4, 026, 198, 428
Total capacity with 15 feet rise at dam	620, 782, 720
Surplus	3, 405, 415, 708

This must be sought to be retained above this reservoir by future examinations.

	Cubic feet.
Contents of reservoir for 90 days	620, 782, 720
Contents of reservoir for 1 day	6, 897, 586
Contents of reservoir for 1 second	82

UPPER SAINT CROIX LAKE RESERVOIR.

Total area lake surface, 1.8 square mile	50, 172, 400 square feet.
Which multiplied by 12 feet depth =	602, 068, 800 cubic feet.
Overflowed area 14.7 square miles	409, 620, 100 square feet.
Which multiplied by 10 feet depth	= 4, 096, 201, 000 cubic feet.
Total capacity	4, 698, 269, 800 cubic feet.
Supply:	
Area of watershed 290 square miles =	= 8, 084, 736, 000 square feet.
Which multiplied by 0.7 foot one-third rainfall	5, 659, 315, 200 cubic feet.
Deduct capacity	4, 698, 269, 800 cubic feet.
Surplus	961, 045, 400 cubic feet.
From reservoir full for 90 days we have per day	52, 202, 998 cubic feet.
From reservoir full for 90 days we have per second	604 cubic feet.

TOTOGATIC RESERVOIR.

Capacity:

Area of surface overflowed 7,635 square miles	= 212, 855, 000 square feet.
Which by various depths will give	2, 881, 095, 000 cubic feet.

Supply:

	Square feet.
Area of watershed, 330 square miles	9, 199, 872, 000

	Cubic feet.
Which multiplied by 0.7 foot, one-third rainfall	=6, 439, 910, 400
Deduct capacity	2, 881, 095, 000
Surplus	3, 558, 815, 400

Which must be sought to be retained by further examinations.

	Cubic feet.
Capacity gives per day	32, 012, 166
Capacity gives per second	370
Could the surplus be retained above we should have added per day	39, 542, 393
Per second	457

UPPER SAINT CROIX REGION.

Yellow Lake and River reservoir.

Capacity of reservoir:

	Square feet.
Lake proper, surface 4,664 square miles	= 129, 913, 344

	Cubic feet.
Which multiplied by 18 feet	=2, 340, 500, 000
Overflowed area 3,936 square miles, which by varying depth, elsewhere computed gives	1, 062, 212, 000
Total capacity	3, 402, 712, 000

Supply:

	Square feet.
Area of watershed, 321.5 square miles	=8, 962, 905, 600

	Cubic feet.
Which multiplied by 0.7 foot, one-third rainfall	6, 274, 033, 920
Deduct capacity	3, 402, 712, 000
Surplus	2, 871, 321, 920

This must be sought to be retained by further examinations next year.

	Cubic feet.
From reservoir full for 90 days, we can furnish per day	37, 807, 911
Per second	438
Could we retain surplus above we could add per day	31, 903, 577
Per second	369

TABLE D.—*Discharge of the Mississippi and Leech Lake Rivers.*

Date.	Station.	Height above low-water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
1874.					
September 8	Above Cass Lake	Mean H. W.	482	1. 074	517
August 22	Below Cass Lake	1. 855	443	2. 012	891
August 15	First station Leech Lake River	1. 536	544	1. 121	610
September 26	Second station Leech Lake River	Mean H. W.	1, 427	0. 833	1, 239
September 26	Below junction Leech River	3. 931	1, 197	1. 636	1, 958
October 12	Above Pokegama Fork	2. 561	849	2. 914	2, 474
October 15	Below Grand Rapids	Mean H. W.	731	3. 454	2, 525
October 20	Below Swan River	do	1, 513	1. 963	2, 969
October 27	Below Sandy Lake River	do	1, 738	1. 696	*2, 946
November 3	Below Willow River	do	1, 822	2. 077	3, 784
1878.					
October 14	Below Lake Winnebagoshish	Mean L. W.	561	0. 965	541
October 16	do	do	678	0. 808	548
September 21	First station Leech Lake River	do	415	0. 729	303
September 23	do	do	474	0. 605	226
October 21	Above junction Leech River	do	342	1. 821	622
October 21	Below junction Leech River	do	672	1. 354	909
October 26	Below Vermillion River	do	986	0. 936	922

*Height of banks about 8 feet at low-water.

Fridley's Bar.

FIRST SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1875.		*Square feet.*			
April 30	7. 28	8, 324	0. 00029187	3 9554	32, 924
May 2	6. 90	8, 057	0. 00028289	4. 0228	32, 412
May 3	6. 74	7, 982	0. 00028289	3. 9627	31, 636
May 4	6. 65	7, 916	0. 00026942	3. 9056	30, 917
May 5	6. 63	7, 894	0. 00026044	3. 8251	30, 190
May 6	6. 58	7, 859	0. 00026942	3. 7300	29, 314
May 7	6. 52	7, 808	0. 00025595	3. 7594	29, 354
May 8	6. 51	7, 786	0. 00025595	3. 7450	29, 159
Sum				30. 9060	

SECOND SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
June 22	5. 78	6, 944		3. 6803	25, 556
June 23	5. 55	6, 791		3. 6082	24, 503
June 24	5. 43	6, 724		3. 6302	24, 409
June 25	5. 25	6, 594		3. 4855	22, 983
June 26	5. 04	6, 473		3. 4340	22, 327
June 28	4. 57	6, 119		3. 3789	20, 670
June 29	4. 27	5, 926		3. 2324	19, 155
June 30	3. 94	5, 706		3. 1570	18, 014
July 1	3. 63	5, 545		3. 0435	16, 876
				30. 6500	

THIRD SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
July 23	1. 40	4, 154	0. 00019398	2. 0540	8, 535
July 24	1. 35	4, 133	0. 00019398	2. 0030	8, 278
July 26	1. 26	4, 050	0. 00019847	1. 9927	8, 070
July 27	1. 27	4, 061	0. 00019398	1. 9805	8, 042
July 28	1. 30	4, 081	0. 00018949	1. 9303	7, 878
July 29	1. 22	4, 050	0. 00018949	1. 8733	7, 587
July 30	1. 21	4, 039	0. 00018949	1. 8396	7, 430

Sauk Rapids.

FIRST SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
May 13	6. 36	6, 691	0. 00018998	3. 3839	22, 642
May 14	6. 32	6, 673	0. 00018482	3. 4050	22, 722
May 15	6. 24	6, 601	0. 00017449	3. 4389	22 700
May 17	6. 20	6, 565	0. 00017965	3. 2385	21, 261
May 18	6. 34	6, 637	0. 00014352	3. 2393	21, 509
May 19	6. 27	6. 583	0. 00014868	3. 2379	21, 315
May 20	6. 17	6, 535	0. 00015384	3. 2439	21, 199

SECOND SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
June 7	8. 00	7, 679	0. 00022247	4. 0286	30, 936
June 8	7. 76	7, 578	0. 00027666	4. 0049	30, 339
June 10	7. 34	7, 226	0. 00024333	3. 8974	28, 163
June 11	7. 23	7, 140	0. 00022666	3. 8156	27, 243
June 12	7. 10	7, 036	0. 0002100	3. 7540	26, 413
June 14	6. 62	6, 847	0. 00019990	3. 7182	25, 359
June 15	6. 50	6, 778	0. 00019990	3. 6394	24, 668

THIRD SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
July 16	2. 38	4, 379	0. 00010063	1. 9305	8, 336
July 17	2. 34	4, 350	0. 00009612	1. 8666	8, 120
July 19	2. 15	4, 234	0. 000087093	1. 7802	7, 537

Brainerd.

FIRST SERIES.

Date.	Height above low water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1875.		*Square feet.*			
May 26	8. 50	4, 467	0. 00015752	2. 9268	13, 084
May 27	8. 32	4, 402	0. 00015123	2. 9099	12, 819
May 28	8. 47	4, 426	0. 00014492	2. 9836	13, 206
May 29	8. 31	4, 402	0. 00013232	2. 9735	13, 089
May 31	8. 46	4, 437	0. 00014492	2. 9485	13, 082
June 1	8. 57	4, 471	0. 00013862	2. 9535	13, 205
June 2	8. 91	4, 586	0. 00013232	2. 9308	13, 441
June 3	9. 05	4, 690	0. 00013862	2. 8666	13, 444

SECOND SERIES.

Date.	Height above low water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
July 8	3. 62	2, 785	0. 000070588	2. 2933	6, 387
July 9	3. 48	2, 735	0. 000064052	2. 2234	6, 081
July 10	3. 32	2, 675	0. 000083660	2. 2120	5, 917
July 12	2. 98	2. 571	0. 000083660	2. 1302	5, 477
July 13	2. 82	2, 522	0. 000070588	2. 1243	5, 362

Discharge of the Saint Croix River and tributaries, 1878.

Date.		Station.	Height above low water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1878.							
Aug.	30	Dam site in section 35, township 24, range 13.	Low water	172		1. 085	172
	30	do	do	148		1. 661	234
Nov.	3	Above the Namekagon	Low water	266		1. 358	362
	3	do	do	302		1. 212	368
	3	do	do	302		1. 269	383
	3	do	do	302		1. 263	381
Nov.	1	Below Yellow River	Low water	975		1. 249	1, 218
	1	do	do	978		1. 305	1, 276
	1	do	do	997		1. 357	1, 352
	1	do	do	997		1. 262	1, 258
	1	do	do	997		1. 295	1, 281
Oct.	28	Below Crooked River	Low water	1, 024	0. 000275	1. 408	1, 442
	28	do	do	1, 024		1. 418	1, 453
	29	do	do	1, 017		1. 400	1, 425
	29	do	do	1, 017		1. 441	1, 467
	29	do	do	1, 017		1. 329	1, 413
Oct.	23	Below Kettle River	0. 540	941	0. 00132	2. 851	2, 683
	23	do	0. 535	941		2. 834	2, 667
	23	do	0. 530	938		2. 897	2, 716
	23	do	0. 520	935		2. 826	2, 642
	23	do	0. 520	935		2. 894	2, 705
Oct.	18	Below Snake River	0. 580	1, 494	0. 000551	2. 176	*3, 252
	19	do	1. 888	1, 872	0. 000771	3. 489	*6, 533
	19	do	1. 886	1, 858		3. 284	*6, 103
	19	do	1. 884	1, 849		3. 421	*6, 425
	19	do	1. 670	1, 801		3. 355	*5, 740
	19	do	1. 090	1, 658		2. 605	*4, 321
	21	do	1. 224	1, 387		2. 177	*4, 010
Oct.	15	Below Rush City	0. 340	2, 420	0. 00031	1. 059	2, 564
	16	do	0. 480	2, 420		1. 117	2, 705
	16	do	0. 480	2, 420		1. 109	2, 685
	16	do	0. 490	2, 426		1. 124	2, 718

*These large discharges were caused by the opening of Snake River Dam at Chengwatana. The height above low water will show this.

Discharge of the Saint Croix River and tributaries, 1878—Continued.

Date.	Station.	Height above low water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1878.						
Oct. 5	Three miles above Taylor's Falls	0.815	1,962	0.000148	1.782	3,499
5	do	0.835	1,948		1.724	3,360
5	do	0.875	1,967		1.733	3,410
7	do	0.730	1,906		1.679	3,199
7	do	0.715	1,899		1.640	3,177
8	do	0.620	1,860		1.618	3,010
8	do	0.620	1,860		1.642	3,055
8	do	0.620	1,860		1.594	2,964
8	do	0.635	1,866		1.654	3,086
9	do	0.620	1,860		1.622	3,019
9	do	0.635	1,866		1.611	3,008
9	do	0.660	1,877		1.623	3,041

Tributaries.

Date.	Station.	Height above low water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1878.						
Oct. 11	Totogatic dam site	Low water	201		1.468	221
11	do	do	230		1.193	260
12	do	do	202		1.487	284
12	do	do	230		1.286	279
Nov. 4	Namekagon River	Low water	557		1.243	692
4	do	do	557		1.378	768
4	do	do	557		1.418	790
4	do	do	557		1.427	795
Oct. 30	Yellow River at dam site	Low water	528		0.414	209
31	do	do	528		0.361	181
Oct. 25	Kettle River	Low water	458	0.001037	0.850	390
25	do	do	458		0.682	313
25	do	do	458		0.795	365
25	do	do	458		0.739	339
25	do	do	458		0.739	338
25	do	do	458		0.711	326
25	do	do	458		0.809	373
Oct. 21	Snake River (dam open)	Low water	591	0.00691	4.302	2,545
21	do	do	591		4.240	2,517
21	do	do	578		4.153	2,402

Discharge of the Chippewa River and tributaries.

Date.	Station.	Height above low water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
1878.					
Nov. 15	Above the Flambeau	0.700	738	1.326	979
16	Below the Flambeau	0.700	1,621	1.132	1,834
Oct. 7	Above the Yellow River	2.000	2,649		3,501
14	At mouth	1.500	1,886	3.284	5,713
Sept. 27	do	0.700	1,256	2.425	3,046

TRIBUTARIES.

Date.	Station.	Height above low water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
Sept. 30	Manatonish River	Mean L. W.	231	0.637	147
Oct. 20	do	do	262	0.789	205
Sept. 4	Turtle River	do	144	0.280	40
Aug. 27	Butternut Creek	do	76	0.280	22
	Flambeau River	do			
Nov. 16	East Channel	0.700	358	2.002	717
	West Channel	0.700	297	1.378	410
Oct. 7	Yellow River	Mean L. W.	112	1.089	122
7	Eau Claire River	0.800	243	1.299	317
12	Menominee River	Mean L. W.	332	1.669	555
12	Aux Galets	do	125	0.931	116
13	Beef Slough	1.750	731	1.741	1,273

TABLE E.—*List of the elevations above the sea of different points on the Mississippi River from Cass Lake to Saint Paul, Minn. The low-water surface of river is given.*

Station.	Distance.	Elevation.	Total fall.
	Miles.		
Lake Superior	....	602. 00	....
Cass Lake	....	1, 300. 08	....
Lake Winnebigoshish	20	1, 290. 04	10. 04
Leech Lake	....	1, 292 78	....
Junction of Leech and Mississippi Rivers	38	1, 279. 23	20. 85
White Oak Point	15	1, 275. 65	24. 33
Outlet of Pokegama Lake	27	1, 269. 32	30. 66
Head of Pokegama Falls	3	1, 266. 71	33. 27
Foot of Pokegama Falls	3	1. 252. 56	47. 52
Head of Grand Rapids	3½	1, 249. 72	50. 26
Foot of Grand Rapids	¼	1, 244. 69	55. 39
Junction of Sandy and Mississippi Rivers	82½	1, 208. 55	91. 53
Aitken	61	1, 190. 00	110. 08
Brainerd	45	1, 152. 43	147. 55
Crow Wing	10	1, 145. 74	154. 34
Fort Ripley	6	1, 139. 54	160. 54
Head of Little Falls (Ferry)	15	1, 090. 55	209. 43
Foot of Little Falls	....	1, 083. 20	216. 88
Platte River	16	1, 026. 07	274. 01
Watab	9	1, 000. 81	299. 27
Head of Sauk Rapids	6	988. 33	311. 75
Foot of Sauk Rapids	....	977. 00	323. 08
Saint Cloud Mill	3½	960. 50	339. 58
Saint Augusta	$5\frac{6}{10}$	946. 5	353. 58
Clear Water	$8\frac{8}{10}$	936. 0	364. 08
Monticello	$14\frac{3}{10}$	890. 90	409. 18
Elk River	$12\frac{5}{100}$	850. 90	449. 18
Anoka	$13\frac{2}{10}$	826. 60	473. 48
Minneapolis	$17\frac{3}{10}$	794. 40	505. 68
Saint Paul (low water)	13	682. 00	618. 00
	445. 55		

REPORT OF MR. JOSEPH P. FRIZELL, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Saint Paul, December 20, 1878.

SIR: In reply to your request of the 13th instant, for my views as to the quantity of water that may be expected for filling the proposed reservoirs on the headwaters of the Mississippi, and other scientific questions involved in this project, I have the honor to submit the following:

Although the flow of streams depends upon rainfall, and every considerable fall of rain is usually followed by a greater or less increase of volume in streams, the portion of the rainfall finding its way into the streams is a matter of great and perplexing uncertainty, and no province of engineering stands so much in need as this of extended, accurate, and intelligent observation of the various circumstances which affect this result.

Observations have been made for some 25 years past at Lake Cochituate, from which the city of Boston has, until recently, derived its supply of water, of the rainfall on, and discharge from, a district some 19 square miles in area. I am in possession of the results from 1852 to 1875, inclusive, a period of 24 years. The average flow is about 45 per cent. of the rainfall, which has averaged some 50 inches. To show the extreme uncertainty of these results, it may be mentioned that in 1857 the rainfall was 63.1 inches, 74 per cent. of which was represented by the discharge. In 1866, the rainfall was nearly the same, viz, 62.3 inches, only 25 per cent. of which appeared in the discharge. The latter was the lowest percentage shown during the 24 years. The highest was in 1859, being 78 per cent. on a rainfall of 49 inches. The highest rainfall of the period was 69 inches in 1863; the lowest, 35 in 1855. In other words, the variations in the rainfall are as 2 to 1. The variations in the discharge with the same rainfall are as 3 to 1. In 1857 the aggregate discharge was equivalent to 47 inches on the entire drainage-basin. In 1871 it was 15 inches.

The flow of the west branch of the Croton River, which has a drainage area of about 20 square miles, was observed for a period of six years by Mr. J. J. R. Croes, an engineer of the New York water-works. The aggregate flow was 63 per cent. of the rainfall. From data obtained in my professional experience I find that the Concord River, in Massachusetts, which has a drainage area of 375 square miles, carried off during a period of 34 months in 1874, '75, '76 about 41 per cent. of the rainfall.

Mr. S. G. Ellis, under authority of the United States Engineer Department, determined the flow of the Connecticut River, at Thompsonville, Conn., for a period of 47 months, commencing February, 1871. The results are detailed in the Report of the Chief of Engineers for 1875. The aggregate flow, after making a slight correction which appears necessary, amounts to 25 inches per annum, rather more than 50 per cent. of the rainfall.

Whether these results can afford us any guidance under climatic conditions so essentially different, is very doubtful. It will appear that even for the localities to which they relate, they form a very unsatisfactory basis of calculation. If, for instance, we attempt to predict the product of the Lake Cochituate drainage district for any given year, knowing the area of the district, the average rainfall, 50 inches, and the average percentage of flow, 45, the second element of our calculation is liable, for any particular year, to vary between the limits 35 and 69, and the third between the limits 25 and 78. So that it appears within the limits of possibility that the flow might be as low as $8\frac{3}{4}$ inches or as high as 54 inches. According to the theory of probabilities both these results might be expected in the course of 576 years, *i. e.*, assuming every succeeding period of 24 years to present the same variations in rainfall and flow as the one embraced in these records, the lowest rainfall might be expected to occur in the course of 24 years, and in 24 periods of 24 years each, it might be expected that the year of lowest percentage might coincide with the year of lowest rainfall.

Of the quantity of water which falls upon the drainage ground of any stream, a portion flows directly into the stream. It does so, at least, when the rain falls faster than it can be absorbed by the ground. A portion may or may not reach the stream indirectly by sinking into the ground, and reappearing at a lower level. A portion is evaporated, from the ground, from foliage, water-surface, and morasses. A portion, at certain seasons, is taken up by plants. Still another portion, in some localities, passes under impervious strata and flows for long distances, often never reappearing till it reaches the sea. Of this character is the water of artesian wells.

The determination of the proportions in which the water of rains is thus distributed, has latterly, to a large extent, engaged the attention of hydraulicians. I present a brief summary of their labors in this direction, rather to exhibit the extreme uncertainty which prevails on this subject, than in the hope of deducing conclusions of practical value. Evaporation is one of the most active causes of the waste of waters. Water surfaces are constantly exposed to it, and the water which enters the ground is not safe from it till it has reached a depth of 2 or 3 feet. The most extended series of observations of evaporation from water surfaces in the United States was made by the officers of the Lake Survey, in 1861–'67, at different points on Lakes Superior, Michigan, Huron, and Erie. The average monthly results are given in Table 1. A second column, headed "New York," gives the results obtained by the engineers of the New York water-works at one of their receiving reservoirs in 1866. The evaporation was observed by means of a wooden box, filled with water and imbedded in the earth of the embankment. The results are given in inches of water evaporated from a water surface.

TABLE 1.

Month.	Lakes.	New York.
January	0. 69	....
February	0. 72	....
March	0. 92	1. 36
April	3. 06	2. 13
May	4. 84	5. 18
June	5. 57	5. 49
July	5. 79	6. 05
August	5. 28	7. 29
September	3. 38	4. 19
October	2. 37	2. 85
November	1. 49	2. 60
December	0. 84	0. 47
Total	34. 95	....

Mr. J. J. R. Croes, above mentioned, observed the evaporation at one of the storage reservoirs of the New York water-works, from 1866 to 1870. He made the average annual evaporation 24 inches, which is about half the rainfall. He thinks his result entitled to more confidence than that given in the table, which, if it embraced the whole year, would show about 39 inches. It is customary among hydraulic engineers in New England and New York to assume the annual evaporation from water surfaces equal to the annual rainfall, which is probably in excess of the fact. Table 2 contains results of experiments made by Mr. Charnock, at Holmfield, England. They are detailed in the Journal of the Royal Agricultural Society, Vol. X. These results are taken from an abstract in the Minutes of the Proceedings of the Institution of Civil Engineers, Vol. XXI. The evaporation from drained ground appears excessive. I conjecture that it was determined by observing the discharge of the drains and deducting this from the rainfall. If so it includes the flow from the surface as well as the quantity absorbed by plants. The evaporation from water surfaces in England is not on an average equal to the rainfall.

TABLE 2.

Year.	Rainfall.	Evaporation from soil— Saturated with water.	Evaporation from soil— Drained.
	Inches.	*Inches.*	*Inches.*
1842	26.11	30.02	21.56
1843	24.49	31.19	20.11
1844	19.00	37.85	15.40
1845	28.18	31.09	23.26
1846	25.24	33.28	18.38
Mean	24.60	32.68	19.74

These results indicate that large losses from evaporation are to be expected in the drainage grounds appurtenant to these reservoirs, consisting as they do largely of swamps and morasses.

The water taken up by plants constitutes a large deduction from the rainfall. Plants draw up water through their roots, and reject it at their leaves, retaining organic and mineral matters held in solution, water being necessarily the medium through which the plant obtains its nourishment. Many experiments have been made to determine the quantity of water transpired by plants. Not to mention the interesting labors of Woodward, a learned English physiologist, in the latter part of the seventeenth century, we will notice those of quite recent date. M. E. Risler, at Caléres, near Nyon, in the Canton of Rand, Switzerland has recently given his attention to the subject. He operated both in the laboratory, and by observing the flow from the drains of a field placed in favorable conditions for such observations. He states the daily consumption of water for different kinds of crops as follows:

	Inches.		Inches.
Lucerne grass	0.134 to 0.276	Vineyard	0.035 to 0.051
Natural meadow	0.122 to 0.287	Wheat	0.106 to 0.110
Oats	0.114 to 0.193	Rye	0.091
Beans	0.118	Potatoes	0.028 to 0.055
Indian corn	0.110 to 0.157	Oak trees	0.020 to 0.031
Clover	0.114	Fir trees	0.020 to 0.043

Schleiden, at Jena, found for a mixture of clover and oats grown in earth contained in an iron box, which was weighed at intervals to determine the evaporation, a consumption of about 0.0984 inch per day from the time of sowing till the time of harvesting, a period of 129 days. Very careful experiments upon this subject have been in progress for several years at the Observatory of Montsouris, in France. The grain is grown in earth contained in metallic boxes, and similar boxes without grain are used to determine the evaporation proper. The earth in some experiments has been carefully dried and weighed before sowing and after harvesting. The results have not been essentially different from what precedes. To produce a pound of wheat requires the expenditure of from 800 to 2,400 pounds of water, the quantity being small with highly manured earth and large in the contrary case. In the case of wheat, the maximum consumption of water occurs at the period of flowering, from which it diminishes till the grain ripens, when it ceases altogether. It will be seen from the above that a field of grain—wheat, oats, or rye—may absorb between seed-time and harvest as much as 15 inches of water, and a field of grass still more. This fact will go far to explain the difference observed in the yield of different drainage ground, and even of the same drainage ground in different years. These results appear also to throw some light upon other obscure questions in hydrology; for instance, the prevalent belief that the destruction of forests diminishes the flow of streams. It appears that the quantity of water required by cereal crops is greatly in excess of that required by forest trees, from which it would appear that the clearing and cultivation of forest lands actually does diminish the quantity of water carried off by streams. They enable us to understand, also, how lands, rich in the chemical constituents of certain grains, produce large crops with a small rainfall, like the north of Dakota and Minnesota, where with a rainfall of 17 inches, 30 and 35 bushels of wheat to the acre is no uncommon yield. The uncertainty of the rain fall as an indication of the flow of streams, has led observers, latterly, to seek for a surer indication in the quantity of water which enters the ground to a depth sufficient to be secure from loss, this being the portion which goes to maintain the ordinary dry-weather flow of streams. It would be more instructive to refer to records of such observations made in this country, did any such exist, which, unhappily, is not the case. Our hydraulic engineers have not hitherto realized the necessity of inquiring so closely into the operations of nature controlling the supply of water. Such observations are made by a percolation gauge, or Dalton gauge, as it is ordinarily called, from Dr. John Dalton, who first directed attention to this subject, near Manchester, in England, in 1796-'97-'98. This gauge, as recently used, consists of an iron vessel, not less than 3 feet deep and 18 inches to 3 feet or more in diameter. It is sunk in the ground and filled with earth, its rim being at the surface of the ground. A pipe leading from the bottom of the vessel enables the water to be drawn off and measured. The surface of earth in the vessel is even with the general surface of the ground, and is usually covered with grass or herbage. Dr. Dalton's average monthly results for the three years 1796-'97-98, are given in Table 3.

TABLE 3.

Month.	Rain.	Percolation.
	Inches.	*Inches.*
January	2. 458	1. 450
February	1. 801	1. 273
March	0. 902	0. 279
April	1. 717	0. 233
May	4. 177	1. 493
June	2. 483	0. 299
July	4. 154	0. 059
August	3. 554	0. 168
September	3. 279	0. 325
October	2. 899	0. 227
November	2. 934	0. 879
December	3. 202	1. 718
Total	33. 560	8. 402

Mr. E. Risler, before alluded to, made observations upon this subject upon a larger scale, by noting the drainage from a field some three acres in extent, underlaid by drains some 4 feet deep and 33 feet apart. He gauged the water discharged by these drains during the years 1868-'69, at the same time observing the rainfall. His average monthly results are given in Table 4.

TABLE 4.

Month.	Rain.	Percolation.
	Inches.	*Inches.*
January	1. 885	0. 914
February	2. 661	1. 603
March	2. 492	1. 894
April	1. 410	0. 000
May	4. 896	0. 106
June	2. 725	0. 051
July	1. 760	0. 000
August	1. 649	0. 000
September	3. 174	0. 000
October	1. 367	0. 000
November	1. 980	0. 783
December	8. 051	5. 728
Total	34. 05	11. 08

Records of percolation have been kept at Hemel Hempstead Herts, England, since 1835, having been commenced by Mr. Dickinson, a paper manufacturer, and continued after his death by his partner, Mr. John Evans. Table 5 gives the results obtained by Mr. Dickinson, being the averages for eight years, 1836-1843, inclusive, with a Dalton gauge filled with the ordinary soil of the district, a sandy, gravelly loam, and grassed over.

The apparent anomaly is presented in table 5 of an infiltration in excess of the rainfall for the month of December. This simply indicates that the influence of rains occurring in November extended into the following month.

TABLE 5.

Month.	Rainfall.	Percolation.	Per cent.
	Inches.	*Inches.*	
January	1. 847	1. 307	70. 7
February	1. 971	1. 547	78. 4
March	1. 617	1. 077	66. 6
April	1. 456	0. 306	21. 0
May	1. 856	0. 108	5. 8
June	2. 213	0. 039	1. 7
July	2. 287	0. 042	1. 8
August	2. 427	0. 036	1. 4
September	2. 639	0. 369	13. 9
October	2. 823	1. 400	49. 0
November	3. 837	3. 258	84. 9
December	1. 641	1. 805	110. 0
Total	26. 614	11. 294	....
Average	....	....	42. 1

Table 6 contains results obtained by Mr. Evans since 1855. His observations extended to the kind of ground known in England as chalk, as well as the ordinary soil of the district. The results are presented in half-yearly periods, viz, winter, commencing October 1, and summer, commencing April 1. A column is added giving the number of wet days in winter, and a column giving the number of days in the year in which more than one-half inch of rain fell.

TABLE 6.—*Results of observations made by Mr. John Evans, at Nash Mills, near Hemel Hempstead Herts, England.*

Year.	Winter commencing October 1.			Summer commencing April 1.			Number of wet days in winter.	Number of days on which more than ½ inch fell.
	Rain, inches.	Percolation, inches.		Rain, inches.	Percolation, inches.			
		Soil.	Chalk.		Soil.	Chalk.		
1855–'56	14. 48	6. 82	10. 47	14. 86	2. 79	3. 09	76	9
1856–'57	11. 96	3. 72	7. 19	14. 11	1. 11	1. 32	71	3
1857–'58	11. 81	5. 64	7. 16	12. 27	6. 80	0. 84	63	5
1858–'59	9. 64	0. 09	2. 69	18. 31	0. 00	4. 22	71	1
1859–'60	16. 49	9. 27	12. 44	20. 40	3. 16	8. 94	93	4
1860–'61	11. 56	7. 61	7. 55	10. 38	1. 13	1. 02	81	3
1861–'62	12. 63	7. 42	8. 19	14. 37	2. 39	1. 77	79	6
1862–'63	11. 01	7. 56	5. 50	13. 40	0. 00	0. 19	82	4
1863–'64	9. 24	3. 18	5. 89	8. 42	0. 35	0. 45	77	2
1864–'65	10. 93	3. 42	3. 55	12. 60	0. 00	0. 00	73	4
1865–'66	20. 00	10. 47	12. 05	15. 59	0. 03	0. 20	113	7
1866–'67	12. 60	4. 64	6. 97	14. 37	0. 18	1. 39	100	4
1867–'68	11. 36	2. 93	5. 36	10. 05	0. 04	0. 42	90	3
1868–'69	17. 58	7. 64	11. 21	12. 80	0. 02	2. 00	104	7
1869–'70	13. 33	4. 50	8. 76	7. 59	0. 00	0. 00	88	6
1870–'71	12. 54	2. 08	5. 35	16. 09	0. 00	1. 72	83	1
1871–'72	11. 25	4. 65	9. 50	14. 44	1. 00	2. 70	85	3
1872–'73	21. 55	11. 25	16. 05	11. 29	0. 00	0. 00	108	7
1873–'74	8. 91	1. 86	4. 40	10. 71	0. 05	0. 65	73	2
1874–'75	11. 69	4. 15	5. 57	15. 03	0. 00	3. 46	87	3
Average of 20 years	13. 028	5. 200	7. 792	13. 352	0. 652	1. 719	85	4

Annual average rainfall, 26.380 inches. Percolation, soil, 5.852; chalk, 9.511. It is stated that Messrs. Dickinson and Evans were enabled by these observations to foretell the quantity of water available for their mill several months in advance, and that orders for the summer are largely regulated by the quantity of infiltration observed during the preceding winter.

Mr. Charles Greaves, engineer of the East London Water Works, in a paper recently presented to the Institution of Civil Engineers, London, details the result of observations made by him during more than twenty years past. He observed the quantity of water delivered by Dalton gauges, a rain-gauge, and an evaporating gauge. A summary of his results is presented in Table 7. The rainfall is very near what may be expected on the Upper Mississippi.

TABLE 7.

Year.	Rainfall, inches.	Percolation, inches.		Evaporation from water-surface.
		In ground.	In land.	
1852	33.500	11.375	....	....
1853	28.500	5.500	....	....
1854	17.500	1.250	....	....
1855	24.714	2.704	....	....
1856	23.812	4.860	....	....
1857	28.627	8.340	....	....
1858	23.899	3.500	....	....
1859	27.767	7.387	....	....
1860	32.558	10.761	23.456	21.058
1861	23.633	5.711	16.360	25.008
1862	26.581	8.549	21.178	17.332
1863	19.766	3.761	16.411	18.266
1864	15.891	3.824	12.636	18.640
1865	29.248	11.150	27.823	20.124
1866	31.697	12.587	28.112	18.821
1867	27.436	5.162	22.424	20.061
1868	23.308	7.112	20.200	26.933
1869	24.562	8.050	22.137	19.062
1870	20.395	7.225	18.699	20.396
1871	24.083	6.118	20.087	19.583
1872	37.166	12.025	30.050	22.916
1873	23.770	4.050	20.120	20.395
Average, 22 years	25.837	6.866	....	....
Average, 14 years	25.721	7.582	21.406	20.613

These results appear to indicate that streams like the Chippewa, issuing from sandy regions, may be expected to keep up better in dry weather than those coming from clay regions, like the Red River of the North or the Upper Mississippi; and that, since the function of reservoirs is to store up the flood-waters for use in times of drought, they promise less benefit to the former class of streams than to the latter.

The vast deposits of unsolidified material overlying the solid rocks are all more or less permeable to water. Pure sand contains, when saturated, 30 to 40 per cent. of its bulk of water; gravel, some 25 per cent. The ground at a certain depth is always found saturated with water, which rises after large accessions from rain sometimes nearly to the surface of the ground, and falls, when not so replenished, sometimes so low that the deepest wells are left dry. In a region of sand or gravel, a fall of 6 feet in the ground-water implies the discharge into the streams of 40 to 55 millions of cubic feet per second per square mile of ground. The water so held constitutes the great reserve which goes to maintain the dry-weather flow of streams. It is, in fact, a subterranean reservoir, filled by infiltration from above, and exhausted by the gradual escape of water to the streams through intervening strata. The ground-water, like the water of streams, is in constant movement, though its movement, as compared with that of streams, is exceedingly slow. Thequantity of water flowing in an open channel 100 feet wide and 6 feet deep, with a fall of one foot in a mile, is about 1,000 millions of gallons per day. The quantity flowing through a channel of the same dimensions and slope filled with gravel would not exceed 600 gallons a day. This extreme slowness with which the ground-water moves serves, in some degree, as a regulating-sluice to the subterranean reservoir, securing it against rapid exhaustion. The preceding facts and considerations, vague and incomplete as they are, enable us to render a more intelligible account than would otherwise be possible of the relation between rainfall and the flow of streams. The absolute amount of precipitation is less important than the circumstances which affect its loss by evaporation. This agency, which is nearly dormant during the three winter months becomes active in March, and increases through April as well from the increase of temperature as from the prevalence of winds. In May the demands of vegetation are added to those of evaporation proper, and contributions to the ground-water become very small, in some years ceasing entirely.

During the three following months evaporation is at its maximum, and innumerable rootlets are active competitors for every drop of water that enters the ground. Vegetable absorption ceases in September, but evaporation proper does not materially abate till October. Heavy and long-continued rains, occurring between May and October, occasion a temporary rise of the streams, which speedily return to their normal condition, as governed by the supply of ground-water.

To understand how a rainfall of an inch or more can occur at this season without contributing anything either to the ground-water or to the volume of streams, we must consider the capillarity of the ground. The latter, like all porous bodies, is capable of containing a considerable amount of moisture which will not escape by gravity. This moisture, during long periods of drought, is gradually reduced by heat and the demands of vegetation, and in that condition a rain of considerable magnitude is expended in restoring the capillary moisture without bringing the ground to a condition admitting of the escape of water by drainage. What precedes will, perhaps, justify the suggestions I have to make as to the meteorological and other investigations required by the reservoir project, viz:

1. While observations of rainfall, evaporation, temperature, &c., in the several reservoir districts will have great scientific interest, and if continuously kept will be of great utility in the future management of the reservoir system, they will afford us but little aid in our present inquiries, viz: the quantity of water to be expected for the supply of the reservoirs. The attempt to infer this result from such data would lead us into a bewildering maze of speculation and conjecture, promising, so far as I can perceive, no practical issue.

2. Daily measurements of the flow of a stream of known drainage area in each of the several reservoir districts would, it appears to me, afford better guidance on this point than any other data obtainable at equal expense. The results so obtained could usually be taken as a standard for the entire district. Such measurements are not necessarily very expensive. A weir can often be made at a slight expense, and a daily record of the height of water, which is all that is necessary to determine the flow, can be kept by any intelligent person resident in the vicinity at a very moderate expense. Where a series of accurate current measurements, accompanied by gauge-readings, are made upon a stream covering considerable variations in volume, the height, as shown by the gauge, becomes thereafter an approximately accurate indication of the flow. Of course, streams must be shown not liable to artificial fluctuation. Meteorological observations, as collateral and explanatory of such measurements, have great value.

3. Accurate records of the daily stand of the several rivers intended to be benefited by these reservoirs are indispensable, and I would recommend that permanent gauges be established for this purpose.

4. An important question will arise in regard to the reservoirs on the Upper Mississippi, viz: Admitting that they can be filled, can a sufficient quantity of water be drawn from them to materially affect the Mississippi? Suppose, for instance, that it should be necessary to draw temporarily at the rate of 4,000 cubic feet per second for Lake Winnebigoshish, which it is proposed to raise 14 feet, and which lies some 65 miles by river above the Falls of Pokegama, the river falling some 23 feet in that distance. The outlet of Lake Winnebigoshish for some 20 miles has a high-water volume of not over 1,000 cubic feet per second. The increased quantity can only be carried in virtue of an increased slope and cross-section. It appears from the measured discharge of the river in 1874–'78, that an increase of volume from 541 to 891 cubic feet per second corresponded to a rise in the lake of 1.85 feet, from which it appears that when the lake is not more than 1.85 feet above low-water it cannot discharge more than 900 cubic feet per second. Although an increase in volume does not involve a proportional increase in height, it is fair to presume that a discharge of 4,000 cubic feet per second would involve a rise of 6 or 8 feet in the outlet, and that the reservoir could not be drawn upon at that rate after it was more than half emptied. The difficulty will be increased by the dams across the Mississippi at Pokegama and the mouth of the Vermillion, which reduce the slope of the river between Winnebigoshish and Pokegama, and by the discharge of the Leech and Mud Lake reservoirs. This is a subject to which future inquiries should be directed. The difficulty will tend to correct itself by the gradual enlargement of the channel in consequence of the increased discharge.

It appears to me that the cheapest and readiest method of solving the several physical questions connected with the project is to proceed immediately with the construction of a cheap dam at one of the reservoir sites on the Upper Mississippi. A dam, for instance, at Lake Winnebigoshish, consisting of an earth embankment with wooden sluices could be constructed for $40,000. If the operation of the reservoir is found sufficiently encouraging the system can be extended from year to year as the government furnishes the means.

Very respectfully, your obedient servant,

JOSEPH P. FRIZELL.

CHARLES J. ALLEN,

Captain Corps of Engineers, Brevet Major.

METEOROLOGICAL RECORDS FROM OFFICE OF THE SURGEON-GENERAL UNITED STATES ARMY.

Saint Paul, Minn.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	......	......	......	......	......	......	......	......	......	2.07	1.83	1.17	......
1872	0.64	1.15	2.43	3.17	5.97	4.28	4.41	0.93	3.45	0.52	1.91	0.00	28.86
1873	1.31	1.54	1.34	2.44	4.63	7.74	3.83	4.61	2.56	2.57	0.79	0.38	33.74
1874	0.49	1.07	2.24	0.95	1.65	11.67	1.95	3.90	5.76	3.21	1.90	0.72	35.57
1875	1.41	1.72	2.19	2.27	3.06	4.33	0.82	8.74	2.16	1.56	0.84	1.56	30.66
1876	0.73	0.66	1.43	2.23	3.15	2.02	2.73	5.28	2.99	1.27	0.93	0.25	23.67
1877	0.55	0.01	1.57	1.92	5.43	7.13	0.52	2.83	2.56	3.62	1.24	1.42	28.80
1878	1.00	0.67	1.24	2.43	2.33	3.58	4.47	1.43	2.13	1.80	0.61	0.40	22.09
Total	6.13	6.82	12.44	15.41	26.22	40.75	18.73	27.72	21.61	16.62	10.05	5.90	203.33
Means	0.88	0.97	1.78	2.20	3.75	5.82	2.68	3.96	3.09	2.08	1.17	0.72	29.05

Fort Snelling, Minn.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1836	......	......	......	......	......	......	7.28	5.55	4.45	0.55	0.70	0.63	......
1837	0.27	0.35	0.33	0.95	2.65	3.46	2.73	1.32	5.10	3.15	1.37	2.34	24.02
1838	0.65	0.76	0.15	2.41	3.05	4.76	11.11	3.08	0.71	0.16	0.43	0.45	27.72
1839	1.34	0.36	0.71	2.71	3.28	1.80	3.50	1.04	1.61	2.11	1.66	1.07	21.19
1840	0.49	0.49	0.65	1.55	2.31	3.50	2.89	3.40	2.33	2.21	3.22	0.13	23.17
1841	0.24	0.21	1.43	1.40	1.50	4.24	1.57	1.17	6.10	1.55	0.84	1.42	21.67
1842	0.95	0.72	0.44	2.17	1.68	3.73	1.78	4.81	4.85	......	3.46	0.60	......
1843	1.15	1.46	0.82	0.75	3.12	5.22	2.00	1.84	5.14	0.50	1.43	0.27	23.70
1844	1.50	0.72	0.97	5.16	4.50	1.64	4.80	4.37	4.26	0.97	0.77	0.58	30.24
1845	0.49	1.40	2.80	3.15	1.51	6.80	2.56	3.28	2.21	0.66	0.40	0.08	25.34
1846	0.52	0.03	1.71	2.90	2.00	3.10	4.95	3.80	2.33	2.45	2.10	0.21	26.10
1847	0.29	0.11	0.44	0.45	4.96	2.66	3.66	2.49	4.00	0.37	1.71	0.66	21.80
1848	0.62	1.13	1.71	0.18	5.28	2.83	4.60	3.19	2.46	0.68	0.10	0.40	23.18
1849	1.00	0.61	4.11	5.62	6.57	3.14	7.59	9.60	2.75	5.35	1.40	1.95	49.69
1850	1.67	0.83	2.23	2.60	0.57	4.62	6.15	2.97	1.82	0.32	1.68	0.04	25.50
1851	0.20	0.13	1.23	2.68	3.96	2.15	2.60	3.29	3.64	1.18	2.31	0.05	23.42
1852	0.06	0.14	2.04	2.49	4.72	0.08	2.74	0.89	0.72	0.82	0.22	0.15	15.07
1853	0.00	0.01	0.02	0.73	4.08	7.59	1.65	2.57	2.14	0.01	0.56	1.11	20.47
1854	0.72	0.03	1.03	2.51	4.30	3.31	3.92	1.75	6.55	1.23	0.60	5.64	26.59
1855	1.67	0.41	1.84	0.28	1.23	2.38	1.32	4.41	6.26	0.90	2.38	1.67	24.75
1856	0.89	0.18	0.22	4.47	1.62	0.76	2.47	1.09	3.24	3.97	1.70	2.01	22.62
1857	3.48	0.94	0.79	4.25	2.05	6.74	0.65	2.03	2.46	0.00	5.75	2.95	32.09
1867	......	......	......	1.59	2.42	7.42	3.22	2.13	5.39	0.76	......	0.15	......
1868	3.25	2.74	1.40	1.26	3.17	1.50	2.52	6.43	2.21	3.68	2.80	1.25	32.21
1869	1.10	5.12	0.41	0.51	3.10	3.53	4.58	6.37	7.69	0.97	0.58	0.87	34.83
1870	3.09	1.11	2.78	1.11	3.32	0.81	2.63	5.86	2.49	1.39	1.13	0.35	26.07
1871	0.79	0.30	2.11	3.88	2.41	3.46	1.28	3.02	1.56	1.31	0.92	0.74	21.78
1872	0.24	0.25	1.46	0.97	1.80	1.98	2.24	2.77	3.01	0.20	0.50	1.60	17.02
1873	0.48	0.72	0.47	2.61	4.06	3.80	2.54	1.11	1.10	0.75	0.76	0.31	18.71
1874	0.49	0.63	0.33	0.35	1.12	7.77	1.55	1.27	3.45	0.64	0.75	0.21	18.56
1875	0.77	0.63	1.49	1.70	2.24	4.68	1.20	8.82	1.61	0.71	1.29	1.98	27.12
1876	0.63	1.30	2.45	3.00	6.30	1.00	2.10	0.51	6.24	1.17	2.52	1.10	28.32
1877	1.15	0.05	2.60	3.00	14.48	10.60	0.26	2.27	3.00	2.89	0.62	3.20	44.12
1878	1.03	0.35	0.87	1.05	2.77	4.16	5.66	1.80	3.53	2.14	......	......	......
Total	31.22	24.22	42.04	70.44	112.13	125.22	102.30	110.30	116.39	45.75	46.66	31.17	777.06
Means	0.97	0.76	1.31	2.13	3.40	3.80	3.01	3.24	3.42	1.39	1.46	0.94	25.90

The rainfall is expressed *in inches.*

Fort Ripley, Minn.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1849	......	......	......	......	......	......	......	......	......	......	......	......	......
1850	1.36	0.91	1.05	2.67	1.52	6.00	11.92	2.51	1.77	1.45	3.65	0.51	35.32
1851	1.41	0.24	0.26	0.97	5.56	5.50	......	3.15	8.74	1.93	2.82	0.36	......
1852	0.13	0.42	6.61	2.37	3.96	2.10	3.92	1.37	6.40	1.27	3.10	2.87	34.52
1853	0.18	0.34	1.06	1.31	1.45	8.72	4.35	2.64	3.31	0.95	1.18	0.63	26.12
1854	0.67	0.03	0.79	0.97	4.34	3.68	0.62	1.69	4.40	0.91	0.24	0.15	18.49
1855	0.41	0.28	1.12	0.36	1.68	4.88	4.03	3.58	4.95	0.06	1.96	0.24	23.55
1856	0.28	0.08	0.01	4.88	2.01	3.81	4.53	2.11	1.36	3.86	0.72	1.68	25.33
1857	1.67	1.68	0.74	1.16	2.68	5.66	......	......	......	......	0.00	0.46	......
1858	1.21	0.55	0.61	2.15	1.90	1.80	3.95	1.77	4.14	0.44	0.67	0.62	19.81
1859	0.57	0.50	4.49	1.44	5.85	4.00	0.66	1.65	3.87	0.35	2.10	0.52	26.00
1860	0.57	0.72	0.38	1.06	8.23	5.91	2.44	1.50	3.20	4.73	0.99	0.88	30.61
1861	1.10	1.95	0.65	2.80	5.10	4.11	1.89	5.88	3.04	2.36	3.13	0.41	32.42
1862	0.59	0.03	1.35	1.46	1.52	1.65	1.79	1.71	2.17	0.45	0.58	1.09	14.39
1863	0.72	0.50	0.29	0.61	1.89	0.28	0.60	5.47	4.32	1.97	0.31	0.24	17.20
1864	0.32	......	1.40	0.35	0.92	0.90	4.07	1.37	0.90	0.20	0.60	0.40	......
1865	0.00	1.26	1.40	2.05	......	2.27	......	6.50	3.72	......	0.34	......	......
1866	1.20	0.15	1.45	......	0.18	......	......	......	1.34	......	1.96	0.02	......
1867	0.46	1.10	0.42	0.70	2.30	9.80	10.90	1.00	1.10	0.51	1.25	0.80	30.34
1868	1.30	2.15	1.15	2.10	2.60	0.85	6.02	2.26	3.95	1.80	3.50	0.35	28.03
1869	0.65	1.15	......	......	......	......	......	......	......	......	......	0.90	......
1870	1.57	2.48	1.86	0.54	4.30	......	......	......	4.22	1.11	0.34	0.54	......
1871	1.01	0.94	3.49	3.30	0.51	4.91	3.07	4.79	2.38	1.78	4.20	3.64	34.02
1872	1.07	0.71	1.28	1.54	4.35	3.81	6.82	4.10	3.92	2.19	3.64	1.34	34.77
1873	2.09	3.41	2.76	1.19	4.59	9.18	5.46	2.13	1.94	4.71	2.19	1.08	40.78
1874	0.83	0.80	2.00	0.63	2.31	9.30	......	8.20	2.17	2.25	2.60	2.36	......
1875	1.03	1.48	3.35	1.95	4.40	2.33	3.99	3.59	3.05	0.36	1.60	1.04	28.17
1876	0.54	0.94	1.16	1.14	4.10	2.43	1.74	2.60	1.86	1.06	1.29	0.62	19.48
1877	0.86	0.00	0.86	2.38	1.84	4.46	......	......	......	......	......	......	......
Total	23.80	24.80	41.99	42.08	80.09	108.34	82.77	71.62	82.22	36.70	44.96	23.75	519.35
Means	0.85	0.92	1.55	1.62	3.08	4.33	4.14	3.11	3.28	1.60	1.73	0.91	27.33

Fort Ridgely, Minn.

1855	4.63	1.58	3.96	0.68	2.24	3.21	2.44	6.34	5.10	0.80	1.40	2.40	34.78
1856	3.14	0.45	0.17	2.54	1.30	1.46	2.30	1.33	1.00	4.24	0.89	4.38	23.20
1857	5.85	5.54	3.60	2.90	4.95	2.85	1.45	3.25	3.95	0.39	2.84	0.81	38.38
1858	0.85	0.53	0.60	3.66	2.93	1.16	4.75	3.26	2.58	0.96	0.96	0.28	22.52
1859	0.61	0.49	4.22	1.62	6.47	7.04	5.90	1.30	2.54	0.46	1.37	0.83	32.85
1860	0.00	1.20	0.34	1.01	2.27	1.58	2.68	1.06	4.13	1.34	0.53	0.83	16.97
1861	0.40	1.20	1.20	1.71	3.76	1.52	1.09	3.11	2.36	2.81	2.48	0.25	21.89
1862	2.55	1.80	2.95	1.57	1.85	3.48	1.31	6.76	4.94	1.15	0.75	0.94	30.05
1863	0.11	0.33	0.42	0.28	2.75	0.54	0.88	8.17	2.00	1.91	0.33	0.45	18.17
1864	0.22	0.01	1.14	0.14	1.23	1.45	3.89	2.16	0.91	1.76	0.21	1.34	14.46
1865	0.62	2.75	1.05	1.57	4.72	4.24	......	7.52	5.95	2.88	0.22	0.85	......
1866	0.73	0.90	0.99	......	0.09	......	......	......	......	1.15	2.15	0.06	......
1867	0.74	0.88	0.36	1.50	......	......	......	......	......	......	......	......	......
Total	20.45	17.66	21.00	19.18	34.56	28.53	26.69	44.26	35.46	19.85	14.13	13.42	253.27
Means	1.57	1.36	1.61	1.60	2.88	2.59	2.67	4.02	3.22	1.65	1.18	1.12	25.31

Duluth, Minn.

1872	......	......	......	0.54	4.57	4.66	5.83	2.74	5.01	0.42	2.48	0.48	
1873	0.75	0.93	2.29	0.22	3.99	9.79	7.21	2.45	5.06	2.98	1.59	1.16	38.42
1874	0.67	0.61	1.84	0.49	1.80	10.81	2.62	5.62	5.59	3.00	5.44	1.37	39.86
1875	0.86	0.98	2.11	2.82	2.45	1.84	0.47	6.19	1.93	2.60	1.78	1.10	25.13
1876	0.69	0.93	2.16	1.99	3.64	4.57	3.93	3.90	4.21	2.25	2.76	0.83	31.86
1877	1.55	0.10	0.78	1.20	6.28	4.88	3.37	1.48	5.67	3.88	1.05	1.95	32.19
Total	4.52	3.55	9.18	7.26	22.73	36.55	23.43	22.38	27.47	15.13	15.10	6.89	167.46
Means	0.90	0.71	1.84	1.21	3.79	6.09	3.90	3.73	4.58	2.52	2.52	1.15	33.49

Fort Pembina, Dak.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1871	.....	.....	.....	.....	.....	.....	.....	2.95	0.23	1.13	0.54	0.47	.....
1872	0.28	0.25	0.45	2.00	1.90	2.09	3.09	0.82	1.67	1.16	0.53	2.95	17.19
1873	0.41	0.75	0.35	0.39	2.11	2.91	1.30	2.38	2.05	0.56	0.66	0.18	14.05
1874	0.26	0.25	0.35	0.20	1.55	3.41	1.40	2.21	1.54	0.29	0.30	0.12	11.88
1875	0.04	0.03	0.05	0.38	1.05	3.64	2.05	2.37	0.32	1.29	0.23	0.15	11.60
1876	0.14	0.55	0.52	0.55	5.59	2.30	6.66	5.61	0.95	0.34	0.87	0.62	24.70
1877	0.07	0.31	1.14	0.95	4.12	9.58	1.63	0.46	1.50	0.86	0.52	0.90	22.04
1878	0.05	0.21	2.03	3.75	2.22	3.41	3.55	4.32	1.64	4.28	.....	.....	.....
Total	1.25	2.35	4.89	8.22	18.54	27.34	19.68	21.12	9.90	9.91	3.65	5.39	101.46
Means	0.18	0.34	0.70	1.17	2.65	3.91	2.81	2.64	1.24	1.24	0.52	0.77	16.91

Fort Abercrombie, Dak.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1860	.....	.....	.....	.....	.....	.....	.....	0.59	2.09	2.81	2.36	0.94	.....
1861	0.50	0.32	0.56	3.98	6.69	1.85	1.66	4.78	0.33	0.63	1.79	0.30	23.39
1862	0.70	0.90	0.78	1.82	1.61	0.95	1.68	0.29	1.12	0.36	0.35	0.82	11.38
1863	0.15	0.74	0.39	0.04	0.87	0.26	0.79	4.62	1.38	3.29	0.26	0.61	13.40
1864	0.18	0.14	0.94	0.45	0.38	1.72	7.24	1.75	1.60	1.16	0.25	1.04	16.85
1865	0.24	2.08	2.00	4.20	0.83	1.46	.....	3.30	0.60	1.10	0.02	0.08	.....
1866	0.93	0.02	0.62	.....	0.20	.....	.....	.....	0.92	0.99	1.24	0.01	.....
1867	0.95	0.45	1.95	0.45	2.14	6.83	3.70	0.76	0.50	0.03	.....	1.30	.....
1868	1.30	0.60	1.28	0.83	2.48	3.05	4.25	1.38	3.09	0.05	0.27	0.32	18.90
1869	0.10	0.50	0.86	2.26	4.32	1.02	0.50	6.40	5.92	0.10	0.70	.....	.....
1870	0.30	0.38	1.48	0.32	4.04	2.01	2.70	2.80	5.10	1.10	0.10	0.14	20.47
1871	0.60	0.72	1.40	1.36	0.36	4.10	1.62	0.57	1.40	0.62	0.70	1.82	15.27
1872	0.40	0.41	1.50	1.50	4.20	10.15	3.45	2.35	0.90	2.20	0.22	0.55	27.83
1873	0.50	0.51	0.69	2.00	2.20	3.65	0.92	4.03	0.44	0.26	0.14	(?)	(?)
1874	(?)	0.80	0.39	0.70	1.70	8.16	1.29	4.33	0.76	0.60	(?)	(?)	(?)
1875	(?)	(?)	(?)	(?)	3.17	2.96	0.32	2.12	.....	(?)	0.50	(0.90)?	(?)
1876	0.80	0.08	0.66	(?)	0.20	0.50	1.10	1.95	0.45	0.10	0.70	0.95	(?)
1877	0.20	0.10	0.60	1.70	1.35	.....	.....	.....	.....	.....	.....	.....	.....
Total	7.85	8.75	16.10	21.61	36.74	48.67	31.22	42.02	26.60	15.40	9.60	9.78	147.49
Mean	0.52	0.55	1.01	1.54	2.16	3.24	2.23	2.63	1.66	0.96	0.64	0.70	18.44

Fort Winnebago, Wis.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1836	.....	.....	.....	.....	.....	.....	.....	0.16	4.53	0.77	1.28	1.77	.....
1837	0.48	0.91	0.25	2.41	3.18	4.80	5.66	2.89	5.39	0.79	3.23	1.35	31.34
1838	2.03	0.20	0.08	2.98	0.86	2.40	7.67	5.35	2.64	1.49	1.77	0.41	27.88
1839	0.92	0.47	0.79	1.84	3.59	4.53	0.83	4.38	1.43	8.14	1.27	0.76	28.95
1840	0.80	1.17	0.48	1.46	2.03	3.71	5.79	3.47	1.45	4.03	2.68	0.05	27.12
1841	0.18	0.43	1.54	1.49	1.51	5.45	3.70	3.79	6.58	1.25	0.55	1.98	28.45
1842	0.84	0.56	1.71	1.85	1.17	5.04	3.24	2.14	3.45	0.21	3.12	1.18	24.51
1843	0.72	0.62	0.39	2.14	4.18	4.07	1.20	1.22	4.41	0.60	2.67	0.58	22.80
1844	1.51	0.58	1.33	3.52	....	4.07	5.40	5.16	2.73	0.73	1.56	1.75	.....
1845	0.67	2.49	3.10	2.67	1.46	4.09	4.37	1.53	....	.....	....	.....	.....
Total	8.15	7.43	9.67	20.36	17.98	38.16	37.86	30.09	32.61	18.01	18.13	9.83	191.05
Mean	0.91	0.83	1.07	2.91	2.25	4.24	4.21	3.01	3.62	2.00	2.01	1.09	27.43

Fort Howard, Wis.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1836	0.50	1.64	3.20	6.37	5.20	3.50	5.06	2.07	4.78	1.59	2.01	1.72	37.64
1837	1.23	0.88	1.81	3.53	6.48	4.31	5.67	4.25	5.04	1.17	2.89	2.69	40.55
1838	1.97	0.53	0.14	3.41	1.54	6.77	7.03	5.66	3.36	3.29	2.58	1.28	37.56
1839	2.03	1.08	1.85	2.48	3.79	4.05	3.35	2.69	0.77	5.26	2.25	1.68	31.28
1840	0.30	0.30	0.26	4.17	1.69	7.29	5.86	3.79	1.25	3.02	2.05	0.50	33.57
1841	0.58	0.39	1.69	2.11	2.46	5.48	.....	.....	.....	.....	.....	.....	.....
**	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
**	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1850	.....	.....	.....	.....	.....	4.92	6.34	6.94	2.69	1.10	2.59	0.95	.....
1851	1.12	1.50	0.78	1.58	8.50	3.15	5.07	2.67	3.26	1.10	2.26	0.28	31.47
1852	1.77	0.66	3.87	2.97	2.15	.....	.....	.....	.....	.....	.....	.....	.....
Total	9.50	6.98	13.60	26.62	31.81	39.47	38.38	28.07	21.15	16.53	16.63	9.10	212.07
Mean	1.19	0.87	1.70	3.33	3.98	4.93	5.48	4.01	3.02	2.36	2.38	1.30	35.34